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NORTH ATLANTIC TREATY ORGANIZATION

RESEARCH AND TECHNOLOGY ORGANIZATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO AGARDograph 341

The Requirements for an Emergency Breathing System (EBS) in Over-Water Helicopter and Fixed Wing Aircraft Operations

(Spécification d'un respirateur de sauvetage pour aéronefs à voilure fixe et à voilure tournante en mission de survol maritime)

This AGARDograph was sponsored by the Human Factors and Medicine Panel (HFM) of RTO.

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14. ABSTRACT This AGARDograph provides the latest worldwide statistics on survivability from a helicopter ditching. It concludes that the persistent 15% fatality rate is basically caused by drowning. The principal cause of drowning is due to inability to breath-hold long enough to make an escape. The provision of some form of Emergency Breathing System (EBS), whether a re-breather or compressed air unit, would extend the time underwater and hence improve survivability. The development of such units since the Second World War are described, and current available units are included to aid NATO and PfP Nations to review their choice. The importance of producing a course training package prior to the introduction of any new EBS into service is presented. Two examples are specifically cited. Finally, a summary is made of the current EBS situation as we enter into the 21st Century.
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This AGARDograph was sponsored by the Human Factors and Medicine Panel (HFM) of RTO.

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The Requirements for an Emergency Breathing System (EBS) in Over-Water Helicopter and Fixed Wing Aircraft Operations

(RTO AG-341 / HFM-054)

Executive Summary

When a helicopter ditches, it commonly inverts and sinks rapidly. Even if the accident is survivable, the astonishing fact is that fifteen percent of the crew and occupants will perish. The basic reasons why occupants have difficulty making underwater escape, have already been extensively discussed in AGARDograph No 305 by one of the authors titled "The Human Factors Relating to Escape and Survival from Helicopters Ditching in Water" published in 1989.

Since this was completed, the two authors have conducted further research on the principal causes of this regrettably high fatality rate. The conclusion to be drawn is that the occupants simply cannot hold their breath long enough to make an escape, and the cause of death is drowning. The fatality rate does not appear to be diminishing.

In Chapter I, this AGARDograph describes the extent of the problem, provides the latest helicopter ditching statistics, the causes of the problem, the factors determining the time required to make an underwater escape, the factors determining the time available for escape and the rationale for the provision of an Emergency Breathing System. Chapter II describes (a) the development of Emergency Breathing Systems for underwater escape specifically citing progress in the Royal Navy; (b) progress in the U.K. Civilian North Sea Helicopter Operation with special reference to the introduction of a novel re-breathing system; (c) progress in the U.S. with the U.S. Coast Guard pioneering effort in introducing the first oxygen re-breather system into helicopter service, and the U.S. Navy progress with their first procurement of 8,200 compressed EBS units and reports of the first lives saved with this unit - HEED II; (d) the Canadian progress demonstrating the fact, which is very common among military organizations, that it took eight years to introduce a piece of already proven diving equipment, requiring only the tiniest modification into service; and (e) the introduction of EBS into the Italian, New Zealand and Singaporean Navies. Chapter III reviews the currently available emergency air supplies for underwater escape from helicopters on the market or potentially coming to market. This is followed with discussion on the choice of a re-breather or compressed air system in Chapter IV. Chapter V discusses the importance of producing a course-training package prior to the introduction of a system into service and describes a typical package example from the U.S. Coast Guard and a civilian training school at Survival Systems Ltd. in Canada. Finally, Chapter VI summarises the whole situation on EBS as we enter the Twenty-First Century.

Seventeen years ago, there were no EBS for crew or passengers in helicopters flying over water. There were basically three units produced by industry still undergoing evaluation. At the time of writing in the year 2000, there are at least four commercially available compressed air and one re-breathing systems on the market. Some NATO nations are now using them in service, but their use is not universal and it is still restricted to aircrew. Very recently, the re-breather system has been introduced for passengers in commercial helicopters flying over the North Sea, but still unresolved is the decision whether to provide dry or wet training. Going hand-in-hand with this is the fact that there are no regulations in existence not only for the requirements of a system, but also for the air certification and maintenance. Finally, until regulations are introduced, helicopter manufacturers will not consider designing a system into the basic helicopter fuselage.

Spécification d'un respirateur de sauvetage pour aéronefs à voilure fixe et à voilure tournante en mission de survol maritime

(RTO AG-341 / HFM-054)

Synthèse

Généralement, en cas d'amerrissage forcé, les hélicoptères se retournent et coulent rapidement. Même si l'accident n'est pas à priori mortel, il est étonnant de constater que 15% des équipages et des passagers périssent en cas d'amerrissage forcé. Les raisons essentielles des difficultés de l'évacuation sous-marine ont déjà été largement traitées dans l'AGARDographie No. 305 "Evacuation et survie en cas d'amerrissage forcé d'un hélicoptère. Le facteur humain", publiée en 1989.

Depuis lors, les deux auteurs ont entrepris d'autres recherches sur les principales causes de ce taux d'accidents mortels qui est à déplorer. Ils ont conclu qu'il est tout simplement impossible pour les occupants de retenir leur souffle suffisamment longtemps pour effectuer une évacuation, et que la mort s'ensuit par noyade. Le taux d'accidents mortels ne semble pas diminuer.

Le chapitre I de cette AGARDographie décrit l'étendue du problème, fournit les dernières statistiques sur l'amerrissage des hélicoptères, les causes du problème, les facteurs qui déterminent les délais nécessaires pour effectuer une évacuation sous-marine et la justification d'un respirateur de sauvetage. Le chapitre II donne la description (a) du développement de respirateurs de sauvetage (EBS) pour l'évacuation sous-marine, en citant en particulier les progrès réalisés dans ce domaine par la marine royale, (b) les avancées enregistrées par l'opération hélicoptère civil en mer du nord au Royaume-Uni, et plus spécialement la mise en service d'un respirateur novateur (c) l'état d'avancement de la mise en service par la garde côtière américaine du premier système à oxygène à circuit fermé pour hélicoptères, et le premier achat de 8 200 respirateurs de sauvetage à air comprimé par la marine américaine, avec des rapports sur les premières vies sauvées grâce à ces appareils - HEED II (d) les progrès réalisés au Canada, en soulignant le fait, qu'il a fallu huit ans pour mettre en service un matériel de plongée qui avait déjà fait ses preuves et qui ne nécessitait que des modifications mineures, situation qui n'est pas rare dans les organisations militaires, et (e) la mise en service d'appareils EBS dans les marines nationales de la Nouvelle-Zélande, de l'Italie et du Singapour. Le chapitre III examine les différentes alimentations d'air de secours pour l'évacuation sous-marine d'hélicoptères actuellement disponibles ou en cours de développement. Ce chapitre est suivi, au chapitre IV, d'une discussion du choix entre les appareils à circuit fermé et les systèmes à air comprimé. Le chapitre V évalue l'importance de la diffusion d'une documentation de formation avant de procéder à la mise en service d'un nouveau système. Il décrit un exemple type de trousse d'information fournie par la garde côtière américaine, et présente une école de formation civile créée par Survival Systems Ltd. au Canada. Enfin, le chapitre VI résume la situation globale de l'EBS à l'aube du 21ème siècle.

Il y a 17 ans, les hélicoptères effectuant des missions en survol maritime n'étaient pas équipés de systèmes EBS, ni pour les équipages, ni pour les passagers. Essentiellement, il existait trois modèles fabriqués par l'industrie et ils étaient en cours d'évaluation. A la date de cette publication, en l'an 2000, au moins quatre systèmes à air comprimé et un système à circuit fermé sont disponibles sur le marché. Ils sont en service dans certains pays de l'OTAN, mais leur utilisation n'est pas généralisée, celle-ci étant réservée aux équipages. Très récemment, le système à circuit fermé a été adopté pour les passagers d'hélicoptères en survol de la mer du nord, mais la question de savoir quel type d'entraînement à prévoir, c'est à dire hors de l'eau ou dans l'eau, reste à résoudre. Une question associée concerne le fait qu'aucun règlement n'existe ni pour la spécification du système, ni pour la certification de navigabilité ni pour la maintenance. Enfin, il est certain que les hélicoptéristes n'envisageront pas de concevoir des systèmes intégrables dans le fuselage de base d'un hélicoptère avant que des règlements ne soient promulgués dans ce domaine.

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CHAPTER 1

The Problem

On ditching in warm or cold water the inability to breath-hold long enough to make an escape from the rapidly sinking, flooded, inverted helicopter represents a major hazard. This hazard increases in cold water because, in this situation, maximum breath-hold time can be just a few seconds.

In the US Navy Journal, "*All Hands*," (45), McKinley reported vividly the life-threatening situation following a ditching experienced by a US Navy helicopter crew. This is quoted in full below:

"*The impact was tremendous. The helo lost power and dropped 500 feet in five seconds. The disabled Navy HH-46 Sea Knight Helicopter slammed into the Indian Ocean so that one survivor, Aviation Ordinanceman 3rd Class Francis Garcia, is not certain to this day, whether the troop seat he was sitting on just collapsed or whether he was actually driven through the webbing of the seat by the impact. In either case, he was sprawled painfully on the helo's hard deck as seawater began to flood in.*

Aviation Machinist's Mate 1st Class Timothy Chayka, the crew chief of the HH-46 was also blanketed by the torrent of water gushing through the ruptured fuselage.

The force of the crash had snapped the cockpit off from the rest of the aircraft. The pilot, Lt. Steven Rosandich, smashed against the door and broke his jaw. Co-pilot Lt. Gregory LaFare, watched helplessly as the windshield collapsed in on him and Rosandich. The instrument panel crushed against their legs and pinned them in the ruined cockpit. Both flyers were immediately swallowed by the water and behind them; Chayka and Garcia were also sinking in the wreckage. Four men - hurt, stunned, and disoriented, were desperately struggling to save themselves as their shattered aircraft sank between the waves of the Indian Ocean."

The problem is not unique to the naval aviator; it can threaten any military or civilian helicopter pilot, crew, and passengers that fly over water, and for that matter any fixed wing aircraft pilot and crew that may be unfortunate to ditch or crashland in water. Nor is it an uncommon or trivial problem.

1.1 The Extent of the Problem: World-wide Military and Civilian Helicopter Ditching Statistics

Helicopter ditchings are not uncommon. The United States Navy, being the largest operator of military helicopters over water, has published the most extensive data relating to ditchings: the first were reported by Cunningham in 1978, (26). Statistics from the Naval Safety Centre show that from July 1963 to February 1975, 234 helicopters, with a total of 1,093 occupants crashed or ditched at sea. 196 persons died in these accidents, 130 were listed as lost/unknown, and 29 suffered either a fatal injury or an injury which caused drowning. The remaining 37 victims were not injured, but drowned nonetheless. Of the 897 survivors, 437 (49%) egressed underwater. The success rate for aviators trained for underwater egress was 91.5%. The success rate for those who had not been trained was 66%.

In 1992, the United States Navy updated these statistics with a series covering 1977 to 1990. During this period there were 137 accidents and a survival rate of 83% (6). These figures were again updated in 1996: from 1977 - 1995 there was an overall survival rate of 75% associated with survivable Class A over-water mishaps (7). The survival rate associated with night accidents for the AH-1, CH-46, and CH-53 were lower; and for the CH-46, less than 50% of the victims survived. In 1998 data covering 1985 to 1997 were reported (40, 41). The survival rate in the 44 daylight ditchings was 88%; this compared with a rate of 53% in the 23 ditchings that occurred at night. These data confirm the intuitive belief that, from the point of view of survivability, flying over water in a helicopter at night is even more dangerous than during the day.

From 1958 to 1988, the Canadian military (13) had at least seven helicopter accidents in fresh water (data from the late fifties to mid-sixties are sparse and incomplete). Nineteen personnel were involved, of which ten died in three accidents, a survival rate of 47%. From 1967 to 1997, the Canadian Military (12) had 14 helicopter accidents in seawater, 62 personnel were involved, of which six died in three accidents; a survival rate of 90%.

Giry (32) has analysed the French military helicopter accident data. Between 1980 and 1991, 11 helicopters ditched; the survival rate was 65%.

In 1988, Baker and Harrington analysed the RN helicopter ditchings between 1974-1983 (4), they noted that 15 of 43 survivors (35%) reported major difficulties escaping, caused by in-rushing water disorientation; confusion; panic; entanglement with debris; and unfamiliarity with exiting release mechanisms. In the same year, Vyrnwy-Jones and Turner (74) reported that in 47% of RN helicopter accidents between 1972-1984 the helicopter sank or immediately inverted on arriving at the water. Reader (49) reported the British Military army, navy, and air force helicopter accidents between 1972 to 1988. During this period there were 94 accidents involving 342 occupants. There were 58 fatalities and 41 injuries; the survival rate was 83%.

In contrast to the statistics presented above that show a survival rate of 55 - 85% in a survivable accident, the German military reported only one helicopter ditching between 1984 and 1997. In this Sea King accident there were no fatalities (44).

In 1992, Steele Perkins (56) did a brief review of seventeen Royal Navy ditchings between 1982 and 1991. One of the principal conclusions was that the addition of a Short Term Air Supply System for the crew would improve survivability.

On the civilian side, in 1984, Anton (3) reported that of seven survivable accidents in the North Sea between 1970-1983, in three cases the aircraft capsized either immediately on ditching or very shortly afterwards. The susceptibility of an aircraft to inversion after ditching (stability) is closely related to sea state. Of the ditchings examined by Anton, the four that ditched in sea state 4 and higher all capsized. To comply with airworthiness requirements a helicopter has to demonstrate stability in up to sea state 6. In the North Sea, the sea state falls below sea state 6 for only a few months of the year (53). J.D. Ferguson, referenced in the Brooks AGARDograph (14), has compiled a list of 38 helicopters working in the offshore oil industry that ditched in the North Sea between 1969 and 1996. 150 of the 431 crew and passengers involved died; a survival rate of 65%.

In their 1984 Helicopter Airworthiness Panel (HARP) report into helicopter airworthiness (23), the Civil Aviation Authority (CAA) concluded that the accident rate for helicopters operating over the North Sea was 2.0 per 100,000 flying hours, compared to 0.4 for fixed wing aircraft. A subsequent review of accident data by the CAA in 1995 reported that between 1976 and 1993, the offshore industry had undertaken 2.2 million helicopter operating hours in the transportation of 38 million passengers, for the loss of 85 lives in eight fatal accidents. This represents a fatality rate of 3.86 per 100,000 flying hours (24).

In 1993, Chen et al (22) examined 77 rotorcraft ditchings for the Federal Aviation Authority. 42 helicopters overturned immediately, 9 overturned within 90 seconds, and the condition of the remainder was unknown. In those that overturned immediately, there were 23 fatal, 20 serious and 32 minor injuries. This contrasts with the one fatal, three serious, and three minor injuries seen in those helicopters in which the overturn was delayed. A good example of what happens during an immediate inversion following ditching was provided in 1995 by the testimony of a pilot of Canadian Air Forces' brand-new Bell 412 helicopter off the coast of Labrador.

"I could feel the aircraft hit the water. It immediately turned over to the left, to my side. It felt like it started to fill with water about three-quarters of the way over. I felt a lot of stuff hit me as we rolled over. Once we were upside down, I waited for the thing to fill up with water. I reached for the door handles. I could not find the jettison handles or the main handles. I tried that for a little bit and then gave up trying to find the handles. I grabbed hold of the seat and pulled myself down, popped my belt and now that I had myself held down against the seat, I looked for the handles again. I got hold of the emergency jettison handle and reached on that and gave the door a hit with my shoulder and it didn't go. I hit it a couple of more times with my shoulder and it didn't go. By that time I was starting to panic so I got myself up out of the seat turned myself a little and hit the door with both feet as hard as I could and it finally went. Once I felt the door go, I got myself sorted, turned around and out I went. I didn't know which way was up when I got out so I initially let myself go to feel which direction I was going. I ran into what I believe was a door on the way up, it hit me in the head. Shortly after that I broke the surface. Initially I was pretty panicky because I could not see anything, it was 100% pitch-black."

Clifford (25) conducted a review of U.K. military and world wide civilian helicopter water impacts between 1971-1992. The Civil Aviation Authority published these data in 1996. Of the 61 military helicopters examined, 9 floated after impact, 15 had a delayed inversion and 35 sank immediately. The condition of two helicopters was unknown. The overall survival rate was 83.1%. The summary of occupant injuries from this report is presented in Table 1.

Clifford then reported on world civilian helicopter water impacts (REF). There were 98 accidents but his data are confusing because he changed his terminology. He describes 13 helicopters that sank, 15 that sank after a delay, 37 that sank immediately and 29 helicopters in unknown circumstances. The overall survival rate was 62.5%. These data are presented in Table 2.

61 Water impacts included in analysis (1971-1992) 273 Occupants involved	
13 Fatal accidents -	46 Fatalities 38 Drowned 8 Impact injuries - 2 from blade strike - 2 seat failures - 3 catastrophic impact Survival rate of 83.1%
18 Accidents involved fatal or serious injuries 7 Accidents accounted for 20 serious injuries:	
	- 12 spinal compression fractures - 6 unknown injuries
21.3% of water impacts analysed resulted in fatalities 82.6% of fatalities were the result of drowning (where cause of death was known) 29.5% of water impacts analysed resulted in serious or fatal injuries 60.0% of serious injuries were spinal compression fractures	

Table 1 - UK Military Helicopter Water Impacts: Summary of Occupant Injuries. Courtesy Clifford (1996)

98 water impacts included in analysis (1971-1992) 902 Occupants involved	
48 Fatal accidents	- 338 fatalities - 57 crew members - 281 passengers Survival rate of 62.5%
In 24 accidents where the cause of death was known.	
	- 162 fatalities - 92 drowned
52 Accidents involved fatal or serious injuries 22 Accidents accounted for 46 serious injuries: - 14 crew members - 32 passengers	
48.9% of water impacts analysed resulted in fatalities 56.7% of fatalities were the result of drowning (where cause of death was known) 53.0% of water impacts analysed resulted in serious or fatal injuries Out of 52 accidents that involved serious or fatal injury, 12 (23.0%) resulted in substantial damage to or failure of seats.	

Table 2 - World Civil Helicopter Water Impacts: Summary of Occupant Injuries. Courtesy Clifford (1996)

The principal conclusion from all the work was that in approximately 60% of cases the helicopter inverts and sinks immediately, irrespective of whether it is a military or civilian type, and the principal cause of death is drowning. This is in accord with previous data.

The latest review of helicopter ditching accidents, both military and civilian, was conducted at DERA by Turner et al (70) in 1997. Of particular note is the recording of U.S. Army helicopter ditchings in the period between 1972 and 1995. During that time, there were 27 survivable accidents over water, in 9 of them there were fatalities. Unfortunately, only a brief review is made of these 9 accidents, and there is no further mention of the remainder. One unsupported conclusion made in the review states “it is unlikely that the use of passenger emergency breathing devices alone would have reduced the number of fatalities.” Yet, a previous statement in 1995 by Benham et al (8) from the same laboratory further supported the development and introduction of emergency breathing systems into service.

On the basis of an extensive review of the worldwide military and civilian helicopter ditching statistics, it is concluded that a significant loss of life can be expected following “survivable” helicopter ditchings (where “survivable” is defined as an accident in which one would expect passengers and crew to survive impact with the water). It is not possible, on the basis of the available evidence, to conclude that the problem is diminishing. For instance, in December 1999, six marines and one sailor were lost when a CH-46 helicopter crashed into the Pacific Ocean, 24 kms. West of Point Loma, California after take off from the U.S.S. Bonhomme Richard.

1.2 The Causes of the Problem

The question of why so many individuals should perish during a survivable accident has been reviewed extensively by Brooks in his AGARDograph on the human factors of escape and survival from helicopters ditching in water. This was updated in a presentation to AGARD in 1997 (17). In any underwater escape, survival will be determined by whether the time required to make an escape can be achieved within an individual’s breath-hold time.

1.2.1 Factors determining the time required to make an escape

The key factors, in roughly chronological order, that influence the time it takes to make a successful egress include:

1. Aircrew and passenger anxiety. There is the loud explosion when the engine nozzles, which run at 600°C, are suddenly cooled as they hit the water. This can terrify the pilots and crew and result in “paralyzing anxiety”.

2. Equally terrifying, is the sudden in-rushing water. One pilot described this like being hit in the chest by a fire hose.

3. In the process of hitting the water, in at least 50 percent of cases, the helicopter will rapidly sink and rotate. At a time of panic, disorientation and in-rushing water it is necessary to take a good breath before the submersion. Two factors make this difficult: (a) There is often very little warning of the ditching. (b) If the accident occurs in cold water (i.e., water below 15°C) it may be very difficult to control breathing (see below).

4. Disorientation. Broadsmith (11) has modeled various helicopters and concluded that a helicopter may rotate several times before settling on the bottom or stabilizing out. The survivor, under such circumstances, will be disoriented due to false cues signaled by the organs of balance in the inner ear, loss of gravitational references and darkness or, paradoxically, by bright surface sunlight reflecting off the bubbles in the in-rushing water.

5. The victim must release him or herself from the seat harness and, by a process of swimming and dragging, move to, and make an escape through, a door, window, or hatch. This is more difficult for those seated at some distance from an exit. An exit may no longer resemble, in terms of either shape or function, its pre-accident condition. The escape is also made more difficult by: the restrictions of a highly buoyant survival suit; panicking survivors; corpses; personal equipment that has been hurled around the cabin; and seats and consoles displaced during the impact. Finally, the helicopter is primarily designed for emergency egress on land rather than underwater.

6. The victim, possibly injured, certainly terrified, disoriented, and at the limit of breath-holding, is capable of only a few simple actions to save his or her life. At this stage, a poorly designed, complex and tortuous escape route, or a confusing jettison mechanism will easily defeat them.

7. Adding to the problems, Allen et al (2) have demonstrated that underwater, even in the best conditions, humans cannot see further than 3.1 meters.

8. Because the majority of life rafts are stowed inboard, in all this confusion, the survivor has to decide whether to use up precious air by holding his/her breath to locate, release and jettison the liferaft, or make as rapid escape as possible without it (20).

9. Once at an escape exit the jettison mechanism must be found and operated. Brooks and Bohemier (15, 18) observed great difficulty locating, finding and operating escape mechanisms underwater under the best of conditions. The choices open to a potentially disoriented victim vary greatly in terms of: lever position; direction of operation; whether the lever matched the task; and whether the door, window, or hatch jettisoned in or out. Brooks and Bohemier examined 35 types of marine helicopter and noted 23 different types of jettison mechanisms. They concluded that little thought had been put into the design of the helicopter for underwater escape; manufacturers had simply taken the principle of emergency ground egress from their land-based design and adapted it for the marine helicopter.

10. Even if the survivor has made a safe exit from the fuselage, it is still necessary to breath-hold until reaching the surface. As the helicopter sinks, it is not uncommon to have to make an escape in 5-10 metres of water. Due to Boyle’s Law, below about 5 metres, neither the buoyancy in the survival suit or the lifejacket will bring the person safely to the surface. It is therefore necessary to swim. This requires hard work and significantly shortens breath-hold time.

1.2.2 Factors determining the time available to make an escape

In the absence of any artificial aid, the time available to make an escape from a ditched, submerged helicopter is determined by maximal breath-hold time. Unfortunately, sudden immersion in cold water produces a series of physiological responses, one of which is an increase in respiratory drive and the loss of the ability to breath-hold. In 1989, Tipton (62) described the initial responses to immersion in cold water which have been given the generic title "cold shock (60); they begin in water at about 25°C and peak in water at 10°C (68). They include: an inspiratory "gasp" response and uncontrollable hyperventilation producing a significant reduction in breath-hold time and an increase in blood pressure, heart rate and the consequent work required of the heart. Tipton et al demonstrated that cardiac arrhythmias are not uncommon during the first minute of immersion; they are particularly prevalent if the face is immersed immediately following a breath-hold (67).

The cardiovascular responses initiated by immersion can be particularly hazardous for those with pre-existing cardiovascular disease. For the otherwise fit and healthy individuals it is the respiratory responses that represent the greatest threat. Indeed, a good deal of statistical, anecdotal and experimental evidence exists to support the view that it is the loss of control of respiration during the first minute of immersion, rather than hypothermia, which represents the greatest threat associated with immersion in cold water (60). This threat is increased if the immersion is in choppy water where the airways will be repeatedly challenged, or involves a period of forced submersion, such as in a sinking craft.

Reduced maximum breath-hold times resulting from the gasp response have been reported by several authors (35, 36, 39, 57, 61). Hayward et al (35) reported that over a water temperature range of 0-15°C, the maximum breath-hold time of subjects was reduced to 25-30% of that seen before submersion, and to 30-60% of that seen on immersion in thermoneutral water. In some individuals, maximum breath-holds of 1-2 minutes in air can be reduced to a matter of seconds on immersion in cold water. As the cold shock response demonstrates both spatial and temporal summation, the size of the reduction in breath-hold time is dependent on the surface area of skin exposed to the cold stimulus and the rate of change of skin temperature. One consequence of this is that clothing can reduce the cold shock response to some extent. Tipton and Vincent (61) reported that the mean maximum breath-hold time of 18 subjects in air was 45 seconds. When performing an underwater escape from a mock-up of a Bell 212 submerged in water at 5°C the corresponding time was 9.5s when wearing cotton overalls; 12.2s when wearing cotton overall plus a "shorty" wet suit; and 19.2 seconds when wearing cotton overalls plus an uninsulated helicopter passenger "dry" suit.

In 1995, Tipton and his colleagues (68) reported that the average maximum breath-hold time of subjects performing a simulated helicopter underwater escape in water at 10°C whilst wearing heavy underclothing and a helicopter passenger "dry" immersion suit, was 17.2 seconds. The corresponding time for subjects wearing the Royal Navy winter sea helicopter aircrew equipment assembly and an aircrew helmet was 21 seconds in water at 5 and 15°C (69).

1.3 The Solution? Rationale for the provision of Emergency Breathing Systems

Despite the evidence to suggest that the cold shock response represents the greatest hazard to be faced on immersion in cold water, the preoccupation remains with hypothermia. This is reflected in: search and rescue policies; the standards, guidelines and specification for immersion protective clothing – few, if any of which, include consideration of the protection provided against cold shock; and the claims made for immersion protective equipment. Whilst it is now

almost unthinkable that anyone should fly over cold water in a helicopter without protection against hypothermia in the form of an immersion suit, many still fly without any respiratory protection. Until relatively recently EBS were not even considered for aircrew, let alone passengers.

It is impossible to accurately predict the time required to make a successful underwater escape from a ditched inverted helicopter. Estimations from groups such as the Coast Guard, military and civilian operators in the North Sea and training establishments suggest that in reasonable conditions (lighting, number of passenger, seating position in cabin) 40-60 seconds are required (68).

Brooks and Muir (19) have recently completed a study to measure the escape times for a full complement of passengers in the Super Puma helicopter. In the first part of the study, fit, healthy helicopter underwater escape trainer (HUET) Instructors and Canadian Navy divers represented the 18 passengers. The HUET (Modular Egress Training Simulator [METS™]) was in an Offshore Petroleum Industry Training Organization (OPITO) standard, 18 exit, configuration. The subjects conducted a total of four underwater escapes; one of these was in the dark. Breath-holding times were measured from the time the heads of the subjects were submerged to the time when the head of the first and the last subjects to egress broke the surface of the water. It took 17 seconds from the HUET hitting the water to the heads being submerged.

In the first submersion and inversion, the first subject took 43.5 seconds to escape and the last subject 109.2 seconds, representing a breath-hold requirement of 27-92 seconds. Ten out of 18 subjects used the emergency air supply in this immersion. In subsequent runs the breath-holding time of the last person out ranged from 33–38 seconds. The EBS provided was used by; four, six, and seven subjects in the subsequent three tests.

In the second part of the study, 15 fit, healthy HUET Instructors and Canadian Navy divers repeated the same experiment in the METS™ in the Canadian Super Puma Hibernia oil field offshore helicopter configuration. The breath-holding time of the last person out ranged from 28-52 seconds in daylight, and from 38-55 seconds in darkness. The EBS was used by five subjects in the first immersion, six subjects in the second immersion, and eight subjects in each of the last two immersions. These were the best times that the highly qualified instructors could achieve in warm water when fully prepared and practiced.

It is the short fall between the maximum breath-hold time of well-protected individuals performing simple mock helicopter underwater escapes in cold water (about 17-21 seconds), and the time thought necessary to make an escape in a real accident (40-60 seconds), which provides the rationale for the provision of some form of EBS. Some have argued that in a real accident individuals would hold their breath longer than the time measured in the laboratory during a mock up. This position ignores firstly, the fact that the reduction in breath-hold time is caused by uncontrollable cold shock, not conscious decision and secondly, that in a real accident it is very possible that the conditions to which victims will be exposed will be much worse than those employed in the laboratory.

In 2000, Brooks et al (21) provided further evidence for the requirement for an additional breathing aid. They measured the breath-holding ability in water of 228 students who either worked in the offshore oil industry or were training for potential positions offshore. The group was randomly selected from the Survival Systems Ltd. helicopter underwater escape training classes between January and March 2000. The average (standard deviation) breath-holding

ability was 39 (21) seconds. The water temperature was 25^{0}C. There was no correlation between age, sex, smoking habits, forced vital capacity or breath-holding in air. However, SCUBA-trained individuals had a significantly longer breath-hold 47.4 (21.6) seconds.

It is concluded, that the aspiration of water resulting in drowning is the principal cause of death in survivable helicopter ditchings and, consequently, an EBS could represent an essential aid to survival. Hence, the logic for adding the provision of some form of EBS to the list of safety-related features for helicopter crew and passengers, and for pilots and crew of fixed wing aircraft who fly low over water. A list which already includes: immersion protective clothing with air relief valves; manually inflating lifejackets; underwater lighting; training in underwater escape; window and door jettison mechanisms. This conclusion is supported by anecdotal evidence; two accounts are presented below.

In the first, the Royal Navy pilot of a Sea King "in the dip", tracking a submarine, provides a vivid description of the problems to be faced after ditching.

"The thing I remember most about the aircraft crashing is the force that the water came in. It really came in so quickly and so violently that you couldn't help but be thrown around in the harness, and I remember hitting my head on the back of the seat plenty of times. It went completely black, of course, and there was the initial shock with the realization that we'd actually crashed. After all the bubbles and the violent motion stopped, I went for the five-point harness and that went straight away, the straps just fell away. Then I went to get out.

I reached for the sliding part of the window instead of jettisoning it, which was probably because I've used that part of the window, the sliding part, thousands of times, whereas I'd only jettisoned the window five or six times in practice. And when you are in that sort of situation, you don't stop and think about things too much. The first time I tried it, it wouldn't budge. I realized then, after only a few seconds under the water, that I was desperately short of air. So, I went for the STASS (Short Term Air Supply System). That worked straight away and gave me such a feeling of relief that I'd actually got something that was going to give me a little bit more time and the panic subsided again for a little while.

I went for the window a second time and it still wouldn't shift, although I found the mechanism quite easily. I realized then that I was breathing much too rapidly on the STASS as well, and if I didn't do something about it, I was going to use all the air up in no time at all. So, I stopped and slowed my breathing down and made a deliberate effort and went for the window a third time. This time, it opened.

I left my seat and got about half way out through the window when I realized I was being snagged by the PSP (Personal Survival Pack), so I reached down and found the two Martin Baker clips on each side and released those. I went to get out, thinking I'd be free then; but, of course, there was the third connector in the PSP, I was snagged again. So, I reached back into the cockpit and found the snagged connector and released that. I got out. I was completely out of the window now, outside of the cockpit. But, it was so black that I had no idea which way was up, which way the surface was. While I was thinking about it, I naturally started floating upwards and when I looked above me, I could see it was slightly less black that way than down beneath me. So, I swam to the top, which seemed to take ages; a good three or four strokes. Much longer than I'd expected.

When I got to the top, it was just such a relief to get on to the surface of the water. I was breathing on the STASS through the whole time, and with this air, I was just so pleased to get to the top, I thought I was safe at last.

The second anecdote is the account of the ditching of an OH-58D at sea. It comes from Flight Fax, May 1992, CW2 David B. Whalen, 4th Squadron, 17th Cavalry (Air) (Recon), Fort Bragg:

"It was a beautiful night to fly - at least 90 percent illumination and not a cloud to be seen. I was flying from the left seat in the flight-lead position. We were about an hour and a half into the mission and on our way back to the ship, I was using the sight to locate the ship when I felt the helicopter yaw right. I looked over at my right seater's display and saw the engine-out warning light. No big deal - except when you're flying at 30 feet and 80 knots over nothing but water. I knew that without a doubt on this night we were going to get wet. I remember thinking "this is going to hurt" as I reached for the floor mike switch. I made the radio call, but I don't think it got out.

We hit the water in a tail-low attitude. The tail boom broke off, pulled the fuselage a little higher, and then everything was dark and wet. Somewhere in the process, I got hit in the face and broke my nose. I don't think I was ever unconscious, but I certainly had my bell rung!

I started swimming, but I wasn't going anywhere. And I couldn't figure out why. I remembered my HEED (Helicopter Emergency Egress Device) bottle, put it in my mouth, cleared it, and took some air. Then I started swimming again, but I still wasn't going anywhere. The air from the HEED had helped clear my head a little, and then I remembered I was still strapped in. I reached down, pulled the release, and immediately started rising. I wasn't sure how deep I was, and knowing that I had been breathing compressed air, I didn't pull my life preserver right away. I had been underwater almost two minutes (believe me, that can seem like a very long time), and I knew that my HEED bottle was almost empty as I broke the surface. What a feeling!

The first thing I did was look around for my right seater. I located him and swam toward him. He had inflated his life preserver and was lying on the surface, but he wasn't moving. When I got to where he was, I started talking to him. He just handed me his radio and said, "I can't get this thing to work." I tried to call our sister aircraft with his radio, then I tried my own. I had so much water in my ears; I couldn't hear an answer. I knew I was bleeding and that there were "things" in the water that would find us soon if we didn't get out. The problem was I didn't know how badly my right seater was hurt.

I had to make a choice - wait for our ship, which was at least ten miles away, or let our sister aircraft pick us up, which could cause further injury to the other pilot. We had been in the water 10 to 15 minutes, and after considering the risks of staying in the water, I decided we had to take the chance and get out. I signaled the other aircraft and saw them drop the ladders.

My right seater reached for his extraction strap. Still not knowing how badly he was hurt, I stayed with him until he was hooked up. In the process, I missed my ladder. Our sister aircraft did a quick pattern and brought up the ladder right to me. I hooked up, they pulled me up out of the water, and I settled in for the flight to the ship. The aircraft came to a hover over the flight deck and we were lowered to it and unhooked. The solid surface of that flight deck had never felt so good.

Beyond any doubt, the fact that we both survived this accident was due to the right training. Without the HEED bottle and the training to use it, without the dunker course and the egress training that goes along with it, without our unit's combat search and rescue training, and without crew and team training, I wouldn't be writing this story. Someone else who saw what happened would be telling it for me."

The reasons given for not providing some form of EBS for aircrew and passengers have been many and varied and sometimes fallacious. They can be grouped under the following headings: "Introduction of new dangers"; "Logistics"; "Lack of a suitable device"; "Increased training requirement"; "Cost"; "Unnecessary". Starting with an historical perspective, some of these topics are explored in the sections that follow.

CHAPTER 2

The Development of Emergency Breathing Systems for Underwater Escape from Aircraft and Helicopters

In the early days of aviation, if an aircraft landed on water, either accidentally or deliberately, it floated (28) This was because it was made out of light materials, such as wood and fabric and the impact was generally at a low speed. The Second World War was to change this. Aircraft were dense, hit the water at high speed, and sank. So much so that the pilots in the Hurricanes that were catapulted from the decks of the Armed merchant ships were ordered to parachute out after their sorties, rather than attempt to ditch alongside the mother ship and try to escape (28)

The concept of providing a source of air to enable a human to escape from an aircraft submerged after an accident is not new, but has not been universally accepted and implemented. Hayes (34) has described the problems associated with the introduction of such a device; the main one being that people vary greatly in their ability to use a demand regulator system effectively. This depends on training, water temperature, individual sensitivity to the cold, the effort expended in escape, the effectiveness and ergonomic interface of the survival equipment, and the severity of the accident.

An A-13 mask and A-14 oxygen regulator with US Navy walk-around oxygen assembly was originally tested and approved for fitting in US Navy aircraft in 1945 (1). The biggest drawback to this system was the weight of the unit. The air valve lever had to be shut off so that only 100% oxygen was being provided, and it was critical to hold the regulator diaphragm on the same level as the exhalation valve of the mask. Holding the diaphragm six inches below the level of the mask exhalation valve resulted in a continuous flow of oxygen. When the diaphragm was held four inches above the mask exhalation valve, oxygen flow stopped. It was, therefore, probably never used.

Davidson was the first physician to document the human factors associated with underwater escape from a fixed wing aircraft in his AGARDograph of 1977 (28). He describes both the pioneering work that he, Beck, and Rawlins conducted in an effort to improve escape from the Royal Navy carrier jet aircraft, and the introduction and use elsewhere of the Dilbert Dunker for underwater escape training. Much research was undertaken to adapt the oxygen regulator to provide a source of oxygen; but the conclusion was that the British system (for underwater breathing) was only favorable if the aircraft remained upright.

In contrast to fixed wing aircraft, Davidson commented that, “Helicopters on the other hand are relatively light. In addition, Naval helicopters have been equipped with flotation equipment and are, therefore, likely to remain on the surface giving the crew plenty of time to escape”. Later he discussed the pros and cons of providing a compressed air supply to helicopter crews and concluded:

“In the majority of helicopter ditchings, the crew escape quickly and without difficulty, so such a breathing device would only prove useful in a very small number of cases. It is, therefore, determinable whether or not the interest in personal safety equipment to be worn by the aircrew, the time required for training and the expense involved, would be worthwhile.”

As helicopters increased in number, weight, speed and passenger carrying capacity, the fatal accident statistics slowly but steadily increased. In the North Sea during the 1970s the fatality rate became significant and a cause of public concern. The question of whether there was any way to improve these gloomy figures arose.

2.1 Progress in the UK: The Royal Navy

In 1975, the Royal Navy re-considered the requirement for an emergency breathing system (52). This came from original ideas from Lt. Miners, Lt. Bartholomen, and Lt. Cdr. Prince who developed the Helicopter Emergency Breathing Equipment (HEBE). A trial was conducted at HMS Vernon in June 1975, with eight aircrewmen from Commando and passenger-carrying squadrons. It was concluded:

- A service requirement existed for HEBE.
  - It should be introduced for aircrewmen in troop / passenger carrying helicopters for assisting passengers.
  - A one-day training course should be developed to train personnel in the use and safe operation of the equipment.

Some important comments and observations came from the subject questionnaire used in the trial. These seem just as pertinent 25 years later for operators considering the introduction of EBS.

- For speed of getting survivors out of a ditched helicopter underwater, a facemask is considered essential.
- Most airmen would have the time to put on their facemask before submerging, remembering that they would first have to remove their helmets.
- During the trial runs, it took between 5 - 10 seconds for the aircrew to take off their helmets.
- The question of the use of a nose clip or not, if a facemask was not provided, got mixed comments. Some found it useful; others did not. The general opinion was that if anything should be provided, it was the facemask.
- More disorientation was produced when the aircrew did not wear a facemask.
- There were two cases where the air hose between the air bottle and the mouthpiece became snagged.

To the best of the authors' knowledge, HEBE did not go into service.

In his extensive AGARDograph on the Principles of Underwater Escape from fixed-wing Aircraft, Davidson (28) reviewed the mechanical problems associated with the provision of an air supply in association with the pulmonary requirements. His comments are quoted in their entirety, as a lesson to aerospace engineers who wish to design new systems for use in helicopters.

To be able to breathe under water one must be provided with a supply of air or oxygen at a pressure approximately equal to that of the hydrostatic pressure applied to the chest. The level of the bifurcation of the trachea is considered to be a suitable datum and thus represents the equivalent centre of pressure of the thoracic cavity.

If the pressure of the gas supplied during inspiration is too low it is not possible for the subject to expand his lungs against the external water pressure. Conversely, an excess of pressure could result in over expansion of the chest and consequent rupture of lung tissue.

It is convenient to use depth of water as a measure of pressure in this context and the limits of tolerance vary in different individuals. It is considered however that a negative

pressure of 30 cms water at the datum level is acceptable, but it is unlikely that satisfactory respiration can be achieved if the negative pressure exceeds 50 cms water. Positive pressure on the other hand could possibly cause lung damage if it exceeds 45 cms water, but, in practice, the oxygen mask is usually lifted off the face by the gas pressure, allowing gas to escape and the pressure to fall to an acceptable level.

Many experiments have been carried out to determine the usefulness of aircraft oxygen systems for underwater breathing. Continuous flow economiser systems do not function satisfactorily under water. These systems incorporate an inward relief valve through which air enters the system once the economiser has emptied. If the pressure in the system drops below the ambient water pressure in the region of the valve, the valve will open and water will enter the system. Even with the oxygen flow increased to as much as 27 litres / min NTP, as could be achieved by selecting the emergency setting on the British MK II regulator, it is unlikely that the inward relief valve will remain shut throughout the breathing cycle. One must remember that 27 litre / min flow at sea level is reduced to 9 litres / min at a depth of 20 metres and this represents only two deep breaths per minute.

Similarly, the small volume obtained from continuous flow emergency oxygen systems is totally inadequate for underwater breathing. Most demand oxygen systems in which 100% oxygen is used or may be selected work well under water. Delivery pressure is normally equal to the hydrostatic pressure applied to the diaphragm of the regulator: therefore, the position of the regulator relative to the datum level is of vital importance.

In aircraft, the oxygen regulators may be mounted on the instrument panel, the seat, the man or the oxygen mask, and aircraft are fitted with regulators of the type, which is most suitable for the particular task that they have to perform. It is unlikely that any modification of existing equipment will be considered for the improvement of underwater breathing performance alone, but appreciation of the limitations of different systems is of value.

The mask-mounted regulator will maintain a relatively constant pressure in the oxygen mask which reduces the problems of possible ingress of water, but with this system the pressure at the datum level may vary by as much as + or - 30 cms water depending on the aircraft attitude. It is, however, likely to be satisfactory provided a sufficient maximum mass flow of gas is available.

Body-mounted regulators are usually on the front of the chest close to the datum level. In this case, the internal pressure in the chest will remain nearly constant with changes in attitude, but the mask pressure will vary from positive to negative relative to the surrounding water as the aircraft attitude changes. A system of this type should function satisfactorily as long as water does not enter the mask.

Seat-mounted regulators are usually mounted at the level of the subject's hip and close to the long axis of the body. When the aircraft is upright the oxygen mask will be lifted off the face by positive pressure in excess of 60 cms water. Breathing is possible as all mask leakage is outboard but the duration of the supply will be limited by the high rate of flow, which will rapidly empty the system. This is not serious, as it is the aircraft sink-rate in most cases, which determines the time available for escape. The continuous escape of oxygen from the mask interferes with vision and hence the necessary actions prior to leaving the aircraft will be dependent upon proprioceptive and tactile information.

If the aircraft inverts, the situation is completely altered. It is not possible to breathe in, due to hydrostatic pressure on the chest and the relatively low delivery pressure. As there is no resistance to expiration it is likely that the occupant will breathe out and be left with his lungs close to residual volume.

The panel-mounted regulator creates similar problems, but, as its position in the cockpit varies in different types of aircraft, one cannot generalize. The same principles apply however, and the distance and direction of the regulator from the chest datum level and the oxygen mask will determine the effects of changes in aircraft attitude when under water.

Experiments have been carried out using a remote pressure-sensing device in an attempt to control the delivery pressure of the regulator. This device (27) had limited success but would have been affected by rapid sink rate of the aircraft and was, therefore, discarded.

So far, only the oxygen regulator has been considered. The design and construction of the oxygen mask are also of importance. The mask usually consists of a rubber molding which has a reflected edge seal and which is supported by a rigid carapace and is secured to the wearer's helmet by a harness, chain or lever system. It has an inspiratory and expiratory valve mounted in the lower half of the mask.

A mask of this type is designed to provide a satisfactory seal during pressure breathing, provided the mask is held firmly against the face. At altitude the regulator provides a small safety pressure. A minor degree of outer leakage is acceptable, as it does not alter the inspired oxygen concentration while airborne. Its resistance to inboard leakage when subjected to negative pressure is less satisfactory.

Under water, while the wearer is sitting upright, the differential pressure across the mask seal is usually positive, thus producing outboard leakage if the seal is not perfect. If for any reason some water does enter the mask, it is expelled through the expiratory valve when the wearer breathes out, thus clearing the mask prior to the next inspiratory phase.

As the attitude of the subject alters, the relative position of the expiratory valve changes and some of the water, which leaks into the mask, will not be removed during expiration, thus making the next breath more difficult to obtain.

The worst situation is obviously the inverted position. Any water, which gets into the mask collects around the nose and cannot be removed via the expiratory valve, which is now at the top of the mask. In addition, the negative pressure in the mask encourages leakage and some water may even enter through the expiratory valve before it closes. In pressure breathing masks, which have a pressure compensated expiratory valve the negative pressure applied to the compensating capsule may tend to resist the closure of the valve and to reduce this effect, a split expiratory valve is used. This modification allows the compensating capsule to load the valve during pressure breathing, but permits the valve to function independently if negative pressure is applied to the compensating capsule.

Even if the regulator and mask function satisfactorily, some aircraft have modifications to enable the emergency oxygen system to work in the air and during airborne ejection prior to separation of the crewmember from his seat. The use of a continuous flow emergency oxygen system requires the fitting of a relief valve to allow excess oxygen to escape at high altitude; but, as ejection at high altitude may result in a long delay prior to separation from the seat, an inward relief valve is necessary to permit the survivor to continue to breathe if the oxygen flow becomes insufficient to meet the inspiration requirement before seat ejection occurs. This inward relief valve, if fitted, is mounted close to the personal equipment connector on the side of the ejection seat and may well be in a negative pressure zone, depending on the site of the regulator. Water will, in that case, be sucked into the oxygen hose between the regulator and the mask, resulting either in the cessation of oxygen supply or in water being sucked into the mask, making breathing impossible.

Underwater breathing is thus possible in favorable circumstances, provided that the aircraft remains upright. It is unlikely that anyone will be able to breathe underwater from an aircraft oxygen system for more than a few breaths if the fuselage is inverted.

The method of supplying oxygen to the system may have an effect on its efficiency. High-pressure gaseous oxygen is the most reliable under water. Trials with liquid oxygen converters demonstrated that a considerable drop in regulator inlet pressure may be expected when the liquid oxygen converter is immersed in water. The formation of ice round the evaporating coils reduces the heat transfer necessary for vaporization of the liquid oxygen and the situation is aggravated if the time between recharging the system and immersion of the converter is short.

It was, however, possible in a recompression chamber trial at the Royal Naval Physiological Laboratory in 1962 for two subjects to breathe with a degree of restriction down to a simulated depth of 150 feet for a period of two minutes from regulators supplied by a single

liquid oxygen converter. Although it is not impossible for an individual to suffer from the effects of oxygen toxicity at partial pressures in excess of two atmospheres, it is unlikely to develop in the time involved in underwater escape from aircraft and it should therefore be ignored in this context.

It has been indicated that subjects breathing 100% oxygen have found subsequent breath holding easier and have been capable of holding their breath for a longer period than they could have done if they had been breathing air. This constitutes a possible benefit from underwater breathing. Underwater breathing on the aircraft oxygen equipment is not always successful and the crewmember of a ditched aircraft must not rely on its satisfactory function.

On the basis of a somewhat questionable assumption that where there was at least one survivor in a ditching, that ditching was survivable, Reader (49) concluded that 28 (50%) of the 55 fatalities in British military helicopter ditchings from 1972-1988 might have been saved by the provision of an EBS. However, twenty (71%) of the fatalities were passengers from one Sea King accident and two were passengers in a Wessex Mk 5. Normally, passengers were not trained in the use of EBS, although it certainly would have been beneficial for some of those in the Sea King. The final conclusion was that eight aircrew might have been saved if a supply of air had been available. In spite of these findings, by 1992 (56) the Royal Air Force and Royal Navy had still not introduced a system into their helicopters that flew over water. Finally, after the Ministry of Defence Procurement Executive produced specifications in 1990, the Royal Navy introduced a Short Term Air Supply System (STASS) into service for aircrew. It was also introduced into the Royal Air Force for crew flying over-water. This unit is an upgraded Submersible Systems Incorporated HEED 2 with a shorter compressed air bottle. It is called the HEED 2-I in the United States. Under normal respiration, it provides up to three minutes of air. This system has already saved at least one life in the ditching of a Sea King helicopter (ZE-419) in 1993, two crew of a U.S. Coast guard HH-65A ditching in 1995, and a ditching of a pilot in a Bell-206 en-route from San Juan, Puerto Rico to St. John's Island, US Virgin Islands.

The UK MoD is currently in the process of procuring an EBS for helicopter passengers. The specification calls for a target duration of 2 minutes breathing support at a working depth of 5 metres, at a water temperature of + 10 degrees C. This should be achievable by an inexperienced user experiencing the shock and conditions associated with helicopter ditching. There should be no requirement for in water training and a simple briefing before, or on departure, should be all that is required. The belief that the requirement for practical in-water training can be "alleviated" by the provision of an EBS of simple design is considered in the following section.

2.2 The UK Civilian Experience

The problem of helicopter ditching is not just a military one. The overall survival rate for North Sea helicopter operations from 1969 - 1996 is 64% (17). A significant proportion of passengers, as well as crew, have been drowned. However, in comparison with the fatalities that have occurred due to thermal problems (e.g. hypothermia) at the surface of the sea following egress, those occurring due to an inability to escape (drowning) have received relatively little attention. As an example, a large part of the fatal accident inquiry into the Cormorant Alpha disaster of 1992, in which 11 of the 17 occupants died, discusses the six fatalities that occurred at the surface of the sea following escape. The quality of immersion suits, hypothermia, survival time and factors influencing this time are considered. Those that failed to escape from the helicopter, in some cases despite having undone their seat belts, are described as "*overcome by the sea*". No consideration is given to why they were overcome or what could have been provided to help.

Such lack of consideration of the "cause of the cause" of death of those failing to escape from ditched helicopters has probably contributed to the delay in accepting the use of EBS for such eventualities. Until relatively recently there was resistance to the provision of some form of EBS and training in its use. A review of helicopter offshore safety and survival by the UK CAA in 1995 (24) provides details of four survivable accidents involving UK-operated offshore helicopters between 1976 and 1993. In these accidents 19 of 54 passengers died, 11 of those who died failed to escape from the helicopter, eight died at the surface of the sea. It is recognized in the report that "*Escape from a submerged helicopter may take longer than the time that a victim can be expected to hold his breath – especially if the water is cold*". Despite this it is still concluded that, "*no clear advantage would be gained* [by the provision of some form of underwater breathing device] *and that, on the basis of evidence currently available, the CAA would not be justified in pursuing this as a regulatory measure*"

In contrast, and on the scientific side, in 1985 two major oil companies in the UK had, in collaboration with the Royal Navy, the vision to commission research into "Submerged helicopter escape and survival". The resulting experimentation by Tipton and Vincent (61) identified the initial response to immersion as a particular hazard for helicopter passengers and crew. A hazard that was <u>not completely negated</u> by either partial coverage wet suits or uninsulated immersion "dry" suits; the maximum breath hold times achievable with this level of protection were still shorter than the time thought necessary to make a successful underwater escape from a ditched helicopter (Chapter 1). It was concluded, "*The problems created by the inability of individuals to breath-hold during cold water submersion could, to some extent, be avoided by providing some form of emergency breathing system. The use of such equipment does, however, require initial training, and introduce the risk of a pulmonary overpressure accident*".

In 1988 the oil companies responded to this conclusion by striving to bring together a group of scientists, manufacturers and administrators who could produce a new approach to immersion protection. The result was the concept of an Integrated Survival System (ISS)(66). For the helicopter passenger this was to include: advanced anti-hypothermia protection; a lifejacket (asymmetric) which, unlike many, would self-right a casualty wearing an immersion suit; and an emergency breathing aid EBS. The fundamental principles behind this concept were that an immersion casualty should be protected against all of the hazardous responses associated with immersion in cold water, and that the individual components of an ISS should be compatible and complementary, they will also be interdependent. As individuals are still being provided with different pieces of protective equipment that have been designed, developed and evaluated separately, this concept remains as applicable today as it was over a decade ago.

Of the components of the helicopter ISS, it was the EBS that was novel. Even more so because the specification given for it by the oil companies was to "*Produce an EBS which is simple in design and which, when used as recommended, can only be of assistance in significantly extending the underwater survival time of the user*" This specification had some significant implications for the design. In particular, the phrase "*can only be of assistance*" ruled out the use of compressed air; this would introduce the potential danger of a pulmonary over-pressure accident. Such an accident can occur when a breath is inhaled from a source of compressed air at depth and an ascent made with a closed glottis (breath-hold). The resulting over-pressure can rupture the alveoli of the lung and, among other things, result in fatal gas emboli. The shallowest depth from which this has been reported to occur during helicopter underwater escape training is 1 metre (9) – this is close to the theoretical shallowest depth. Some potential users of EBS in the

civilian sector had given this danger as the reason for their reluctance to introduce an EBS into widespread use. Implications for training time and cost were clearly also factors.

After detailed consideration of literature relating to the control of breathing, the concept of a simple re-breather was formulated and developed during the late 1980s and early 1990s (68). This device became known as “Air Pocket” and was manufactured by The Shark Group, the only company, of several that had been approached, who had agreed to participate in the exercise to develop an ISS.

It is worth briefly noting the stages of testing that Air Pocket went through in order for those involved with its development to be satisfied that it would safely conform to the prescribed specification (5, 42, 46, 47, 48, 55, 63, 64, 65).

- Unmanned testing on a breathing machine – to determine final design, static and dynamic hydrostatic and resistive performance, and work of breathing.

All manned testing preceded by one-to-one training in the use of the equipment.

- Manned testing in air – to confirm final design, methods of use, maximum duration, and gas concentrations within the re-breather.
- Manned testing in warm water – to determine ease of breathing and subjective responses, initially when seated upright underwater and, subsequently, during 360° forward and sideways rotations.
- Manned testing in cold water – to determine performance in cold water and at pressure. Upright seated immersions wearing full protection (helicopter passenger dry suit, lifejacket, EBS), progressing to simple simulated helicopter underwater escapes at 2, 2.5 and 5 metres depth. Water temperatures 25, 10 and 5°C.
- Manned testing during simulated underwater escapes at a helicopter underwater escape training centre. To examine performance in as realistic setting as possible, checking: comprehension of instructions; operation/ease of use; maneuverability; snagging hazard; subjective comments. Initially using a shallow water egress trainer, progressing to escape from a full sized helicopter underwater escape trainer (HUET). Initially using instructors, progressing to naive subjects.

This progression of testing and evaluation is included because it is precisely what we would recommend be undertaken prior to the introduction of any new EBS (see also Chapter IV). Unfortunately, because no standard exists for such devices, some have thought it enough to jump straight to the final phase and assess new devices in a HUET using only trained instructors/divers. This is not a practice we would recommend; such individuals are extremely comfortable underwater in any position; they are capable breath-holders and comfortable breathing against resistance and controlling their respiratory demand to the capabilities of a system. This is not the case for the average professional passenger or pilot. Such equipment should be evaluated at some stage using a large number of the target population for which the apparatus is developed. In the UK these issues are starting to be addressed by the CAA.

As the above suggests, despite resistance to the concept up until recent times, the rationale for the provision of some form of EBS for helicopter passengers and crew is now generally accepted in the UK by both the military and relevant civilian organizations.

2.3 Progress in the US: The US Coast Guard

The US Coast Guard was alerted to the problem of impaired underwater breath-hold time, and therefore survival time, in 1980. They experienced three incidents where inability to breath-hold in cold water contributed to the demise of some of their crews (14). The first incident occurred in 1977, when eight crewmen were trapped in a large pocket of air in a capsized boat. All had difficulty holding their breath in the 7°C water, even though it was a short swim to escape. Only six crewmen survived. The second and third accidents occurred in 1979, in two HH-3F helicopters. A total of only three, out of the nine, crew survived. Autopsy revealed that none had received any serious injury, and all had simply drowned in the 13°C water. Hayward (35) demonstrated to the US Coast Guard the dangers of sudden cold water immersion and the serious reduction in breath-holding in cold water. This led the US Coast Guard (33) to develop their Underwater Escape Re-breather (UER).

The prototype system consisted of a modified dual-cell life jacket. One cell of the jacket contained an oral inflation tube and 28 gram CO_2 cartridge; the other cell had a mouthpiece with breathing tube and a 12-litre compressed oxygen cartridge. Upon immersion, a pull-toggle manually activated the flow of oxygen and this inflated the left cell of the preserver with 100% oxygen. A prototype life jacket / survival vest combination was produced in 1981.

On behalf of the U.S. Coast Guard, the U.S. Navy conducted the tests on the UER. This model was assigned the nomenclature “HEED 1” (Helicopter Emergency Egress Device). It was introduced into service in 1984 as the LPU-25/P (Figure 1) manufactured by Soniform Incorporated, El Cajon, California (16). It was issued with a training package; this is reproduced later in this AGARDograph as a good example of how the introduction of a new emergency breathing system should be undertaken.

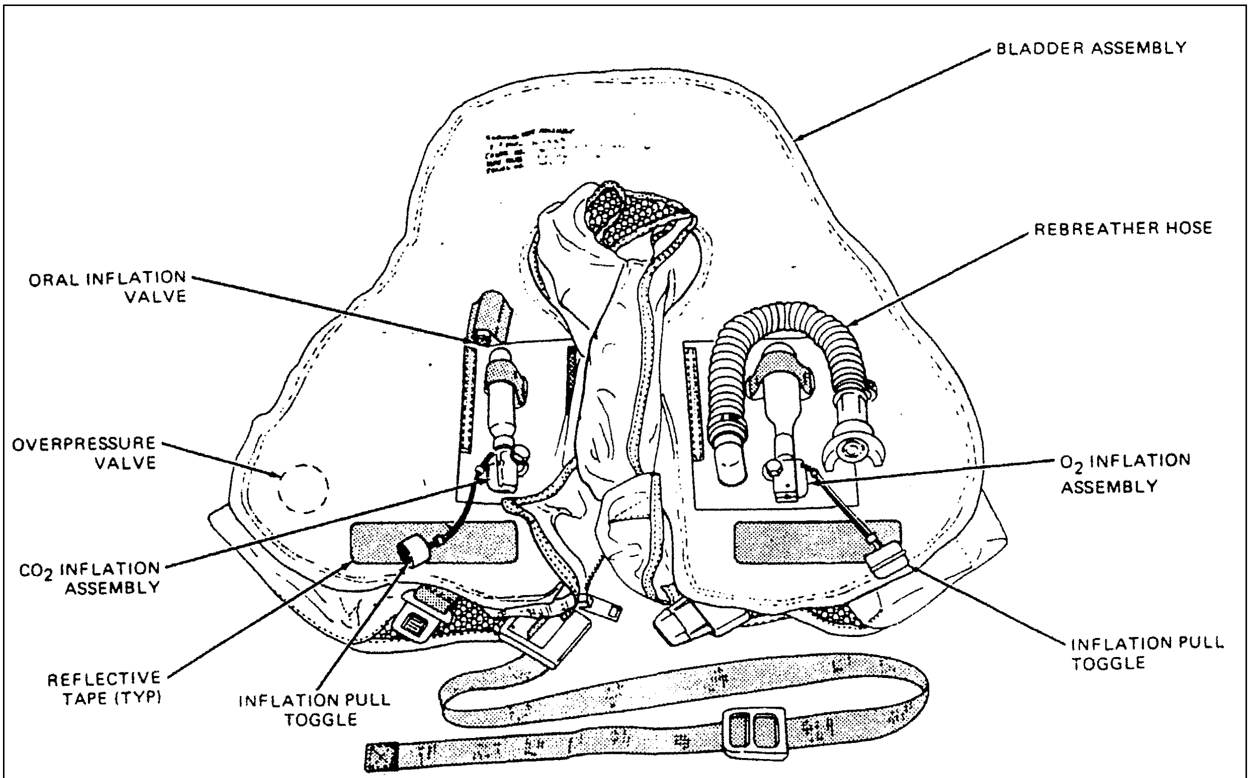

Figure 1 - The US Coast Guard introduced the LPU-25/P Survival Vest Assembly/Underwater Escape Re-breather.
Soniform Inc. of California manufactured this unit, and it was the very first EBS system to go into service in 1984.

In 1973, Rice and Grear (51) first alerted the US Navy to the high fatality rate from helicopter ditchings, and the US Centre was publishing excellent annual statistics (71). Then during the 1980s, the US Navy were further alerted to the problem of breath-holding by Erbewein's article (29) in proceedings. They saw the advances made by Canada (see below) at an Air Standardization Coordination Committee (ASCC) Working Party 61 meeting (50). They purchased a number of MKI units for evaluation and assigned it the nomenclature HEED 2. As described above, they were already testing the UER from the US Coast Guard, which they had named HEED 1. Ultimately the US Navy procured 8,200 of the HEED 2 units and commenced delivery to the Fleet in September 1986 (28).

The US Navy procurement of HEED 2 paid off in October 1987 in the ditching of an H-46, which was described in Chapter I. In this case, four crewmen were directly or indirectly saved by the use of the air supply. An unclassified signal from COMASWINGPAC San Diego R211530Z Oct. 97 summarized the event and is quoted in full.

"The following narrative is forwarded to amplify the role HEED and egress training played following the crash of an H-46 helicopter at sea on 27 August 1987. This was the first reported accident where an aircrew used HEED to escape from a sinking aircraft and two aircrewmen's lives were saved. Prior to deployment, all aircrew on the detachment received HEED training through an accelerated training program provided by NAS Miramar Aviation Water Survival Program (NAWSTP).

Also, all four crewmember's escape is directly attributed to the underwater egress training received from NAS Miramar and NAS Pensacola in the ND-5 [US Navy Dunker].

The aircraft crash occurred in the Western Pacific during daylight hours in moderate seas. The helo experienced a material failure in the transmission during recovery at the bottom of a maintenance autorotation that resulted in a full power loss. The pilots continued the autorotation and impacted the water in a 10-15 degree nose up, wings level attitude. The aircraft sank immediately. All four crewmembers escaped underwater.

As the helo sank, the pilot and crew chief exited the aircraft underwater and swam to the surface. They did not use HEED, but did employ underwater egress techniques and training procedures learned at NAWSTP, which enabled them to safely exit the aircraft. The crew chief exited the helo and swam to the surface immediately with no problem. The pilot was stunned and disoriented after exiting the ACFT and immediately reached for his HEED bottle. He attempted to use HEED, but couldn't open his mouth because of intense pain from a broken jaw. He used a blast of air from HEED to indicate the direction to the surface. Once oriented, he inflated his LPU and floated to the surface.

The co-pilot and 2nd crewman both used HEED to escape. The co-pilot was pinned in his seat by debris from a collapsed instrument panel. His body position was approximately horizontal and his face was turned down and underwater. He was stunned and disoriented, but used the HEED bottle. He had no problem pulling the bottle from the zippered vest and placed the bottle parallel to his body and began to breathe. He did not clear the regulator before taking the first breath of air, but it had no apparent effect other than a small amount of water trapped in the mouthpiece. Even after impact, the regulator worked satisfactorily and he was able to breathe normally. The HEED bottle had an immediate calming effect on the co-pilot. The bottle allowed him time to become oriented and concentrate on egress procedures. He removed the instrument panel from his legs, released his harness, exited the aircraft and swam approximately 15 feet to the surface and breathed regularly, while ascending. Once on the surface, he inflated his LPU [lifejacket]. He sustained a minor cut under his chin, which is assumed to be caused by the HEED bottle.

The 2nd crewman in the cabin section was thrown from his seat to the cabin floor. He was on his knees in chest deep water as the aircraft sank. As the water rushed in, he recalls being dazed and disoriented, but alert. He took a breath of air and reached for his HEED bottle. He easily removed it from the vest pouch. Like the co-pilot, he did not clear the regulator and was going underwater as he took his initial breath of air. Just as the co-pilot had experienced, the HEED bottle had a calming effect on the 2nd crewman. He oriented himself in the aircraft, disconnected his Gunners belt, exited the aircraft, inflated his LPU and floated approximately 10 feet to the surface. He breathed normally while ascending. Like the co-pilot, the crewman also sustained a minor cut under his chin, which is assumed to be caused by the HEED bottle, but the crewman cannot say for sure.

The following recommendations / lessons learned are forwarded:

1. *The HEED bottle is credited with saving two lives. The most important lesson learned in this accident was the apparent calming effect HEED had on both crewmen, as well as providing additional time for the co-pilot to remove the debris from his legs. Although disoriented, HEED restored their confidence and allowed them sufficient time to regain their composure, execute egress procedures in a rational manner and safely exit the helo and swim to the surface.*

2. *The underwater egress training taught at NAS Miramar and Pensacola, is credited with assisting all four crewmembers in successfully escaping the aircraft. The training was particularly valuable since the aircraft hit hard, and sank immediately. There was only 5-8 seconds from the initial failure to impact. All crewmembers report being disoriented and stunned, but remembered their egress procedures. Even though the actual experience was much more intense and spontaneous, the training provided by NAWSTP incorporated the necessary skills for proper use of the equipment in conjunction with a safe egress. The pool training, ND-5, and HEED training were easily applied to this crash situation and are considered realistic and essential to crew survival during an actual emergency. No recommendations are forwarded to improve underwater egress training.*

3. *There was no apparent internal / external damage to the bottles following aircraft impact. The bottles have been forwarded to Navaidevcen Warminster (Code-603421) per Ref C for examination. Following impact, the HEED worked satisfactorily even though the crewmen did not clear their regulators prior to use. Unlike the pilot and crew chief, the co-pilot and 2nd crewman used HEED as the second step in egressing, recommend NAS Miramar debrief the aircrew to discuss use of HEED during egress.*

4. *The placement of the HEED bottle in the crewmen's vest presented no apparent safety hazards in this accident. The crewmen noticed they had identical minor cuts under their chins. Although they do not remember, this may have been caused by their chins being forced down onto the top of the bottle during impact. Neither of the other two crewmen had similar cuts. This may have been caused because one crewman was lying prone on the cabin deck and the other apparently did not have his inertia harness locked. However, recommend review / discuss placement of HEED bottle with aircrewmen.*

5. *There are no apparent medical problems associated with the use of HEED by the two crewmen.*

In 1990, Bohemier et al (10) studied the human factors associated with the use of emergency breathing apparatus to aid underwater escape from a METS™ configured to the commercial

Sikorski S-61 helicopter. The subjects wore either Canadian Department of Transport approved Albatross or Fitzwright immersion suits. After appropriate training, the Submersible Systems Inc. HEED 2, with bottle mounted in the helicopter aircrewman's backpack and regulator on the front of the life jacket, was used.

The EBS increased the number of successful escapes made by naïve subjects. For those who had to make the more complicated escapes there was a 5 to 10 fold increase in the success rate when using the EBS. The EBS was most beneficial for those with more difficult seat assignments, such as the navigator of the Sea King who has to turn 270° and proceed backwards to exit from the main air stairs. The times to escape with and without the EBS were not significantly different; however, the EBS gave the subjects a calming effect and afforded them more time to locate and travel to their exit, then jettison it.

The US Navy was convinced that they had made the correct decision in procuring HEED 2. The Naval Safety Centre has monitored performance since introduction into service. Their first report was published in May 1992 by Barker et al. (7). The observations are tabulated in Table 3.

Comments	Number	Percentage
Needed, not used	4	19
Regulator broken, so it did not have one	1	4.8
Donning / Removed	5	23.8
Improper procedures in use	2	9.5
Dislodged from vest, used	1	4.8
Caused minor injury	2	9.5
Needed, not available	5	23.8
Dislodged from vest, lost	1	4.8
TOTAL	21	100

Table 3 – The US Navy's Observations of HEED 2 Performance.
Courtesy Barker, Yacavone, Borowski and Williamson (1992).

They concluded that HEED had facilitated underwater escape. They reported that there were 25 individuals who reported that they would not have survived without an emergency breathing system. EBS users consistently reported a calming effect replacing the post-impact panic frequently experienced with the initial in-rush of water. So much so, that the Marine Corps were seriously considering training their ground troops and supplying units to those proceeding on over-water missions. It was further concluded that the problems, which were encountered with the device in Table 3, were related to the fact that the unit was an add-on to the existing survival vest and a modification was required to secure it to the vest. The injuries noted were due to failure to properly check that the unit was firmly secured to the vest pre-flight; or simply through contact injury in the impact / in-rushing water phase. Like the soon to come into service Canadian design, the US Navy was modifying the system so that the compressed air bottle was an integral part of the vest. An air hose was added so that only the regulator / mouthpiece need be located, retrieved and placed in the mouth.

In 1991, Yacavone (73) added further evidence for the success of the HEED.

An SH-60B aircraft ditched at sea following an apparent single engine failure and resultant loss of lift during transition to take off. The following are the egress scenarios of the pilot, co-pilot, and aircrewman. The aircraft impacted the water with almost no forward airspeed. The pilot and co-pilot considered activating the aircraft's flotation system, but dismissed it as "too difficult and possibly a hindrance to egress". The helo immediately rolled to the right and soon was inverted and rapidly filling with water.

The pilot got a good breath prior to becoming submerged and attempted to push out his escape window, but it would not push out. Once the violent motion had stopped, the pilot maintained his reference point, released his restraint system and wedged himself between the centre console and the window. Using his feet, he was able to dislodge the window, which he then egressed through without difficulty. Once clear of the helo, he inflated his LPA [lifejacket] and floated to the surface, which he estimated was about 15 feet above him. The pilot did not use his HEED although it was in his SV-2 [survival vest] and functional.

The co-pilot recalls waiting for all violent motion to stop before attempting to release his egress window. The window would not release so he attempted to open his cockpit door. The door opened, the co-pilot released his restraint harness and attempted to egress through the opened door. As he attempted to egress through the open door, the aircraft rolled inverted. The water pressure slammed the door shut, pinning the co-pilot's head and right hand in the door jam, preventing him from getting at his HEED and trapping him inside the cockpit. The co-pilot was now underwater and struggling to free himself against the external water pressure. The co-pilot placed his feet against the central console and attempted repeatedly to release himself from the door. He was finally able to release his right hand, but his head remained pinned. He released his helmet strap and pulled his head from the helmet. He looked around the cockpit and recalled it being "very dark". He saw a light coming from what he thought was the pilot's window. He swam across the cockpit and egressed. Once clear of the aircraft, he recalls being disoriented as to which way was up. He blew some bubbles to find the direction of the surface. The bubbles rose to his feet so he turned around and began swimming to the surface. He did not think to inflate his LPA at this time. The distance to the surface was estimated to be 40 feet. After the aircraft had entered the water, the senso placed the HEED bottle into his mouth and began breathing from it. He stated that this had a tremendous calming effect although he did recall that he had to force himself to breathe more slowly. As the aircraft rolled inverted, he remembered becoming disoriented because he "failed to tighten his lapbelt". The sensation of hanging in his straps disoriented him. After grabbing onto his seat, he released his escape window. The window somehow popped back inside the aircraft, striking him in the mouth and dislodging his HEED bottle.

Rather than relocate it at this point, he released his lapbelt and exited the aircraft. When he reached for his beaded handle to inflate his LPA, he found his HEED bottle dangling on it's lanyard. He cleared it and placed it in his mouth. The Senso then inflated his LPA and floated to the surface.

In the early 1990s, the US Navy decided to update their HEED. They conducted a market survey and procured six new models to compare against the existing in service HEED 2 (31, 33, 54, 72). These were:

1. U.S. Divers Inc. Micra Air System (MAS)
2. Submersible Systems Inc. (SSI) Type I (Figure 2)
3. Submersible Systems Type II (Figure 3)
4. M.C.A. Research Corporation HEED Type II
5. Adams Breathing and Life Saving Equipment (ABLE)
6. Meggitt Oxygen Systems Survival Air System (SAS) (Figure 4)

Figure 2 - Submersible Systems Inc. Type I
This unit was initially introduced into service with the US Navy and is still in service with the Royal Navy.

Figure 3 – Submersible Systems Type II
Note the addition of a hose so that the compressed air bottle can be stowed in the backpack and the mouthpiece stowed on the front of the lifejacket.

During unmanned breathing tests, ten cycles were performed under a specific set of parameters and work of breathing was calculated for each unit. The work of breathing with the ABLE, SAS, and MCA HEED was excessive, requiring inspiratory or expiratory pressures greater than 4kPa. The U.S. Divers Inc. MAS and Submersible Systems Inc. Type I met the requirement for work of breathing in 12.8°C water, and it was recommend that these should be evaluated under the US Navy Water Survival Training Program at Pensacola Naval Air Station. It was noted that the whip connecting the 3000-psi cylinder to the regulator of the SSI Type II presented a significant risk. No further testing was carried out, but there was a final note of caution made on the US Divers System; there was the potential for the regulator on the MAS bottle to be inadvertently unscrewed while activating the bottle. This small risk was also noted and described to students in the maintenance and training classes. Subsequently, the US Navy purchased the U.S. Divers Inc. Micra Air system. They assigned it the nomenclature SRU-40/P (Figure5).

Figure 4 – The Meggitt Oxygen System's Survival Air System (SAS).

Figure 5 – The US Divers Inc., Micra Air System (MAS).
This unit is currently in service with the US and Canadian Navies as the SRU-40/P.

2.4 Canadian Progress

In February 1980, the Canadian Military Flight Safety Office requested that the Directorate of Aerospace Support Engineering conduct the necessary research and development to provide an emergency gas supply for all crew who fly in helicopters regularly over water (37 38, 58). Three systems were considered, the first of which was the US Coast Guard UER. Two prototype units were procured by the Defense and Civil Institute of Environmental Medicine (DCIEM) and tested. They basically passed all their tests. Because there were no commercial units available, and the fact that all the Navy lifejackets would have to be replaced if it was adopted, it was decided to proceed no further with the concept.

The second unit was manufactured by the Robertshaw Controls Co., Anaheim, California (Fig. 6 a and b); it consisted of a coiled, stainless steel tube containing 130 litres of air compressed to 5,000 psig. From the reservoir, a 56 cm hose with in-line quick disconnect fittings connected it to a miniature suction pressure demand regulator and mouthpiece. Pulling a ring at the base of the unit started the air supply. Two units were procured and tested in March 1981 by the Diving Division at the Defence and Civil Institute of Environmental Medicine (DCIEM) in Toronto. During a 75-watt workload at 10 and 30 fsw, the average breathing times were 3 and 2.5 minutes respectively. However, there were constant problems with the mouthpiece, which flooded and regularly needed clearing. This was thought to be due to an inadequately designed flapper valve. Consultation with the manufacturers revealed that the cost to fix it would make the price per unit prohibitive. No further development took place.

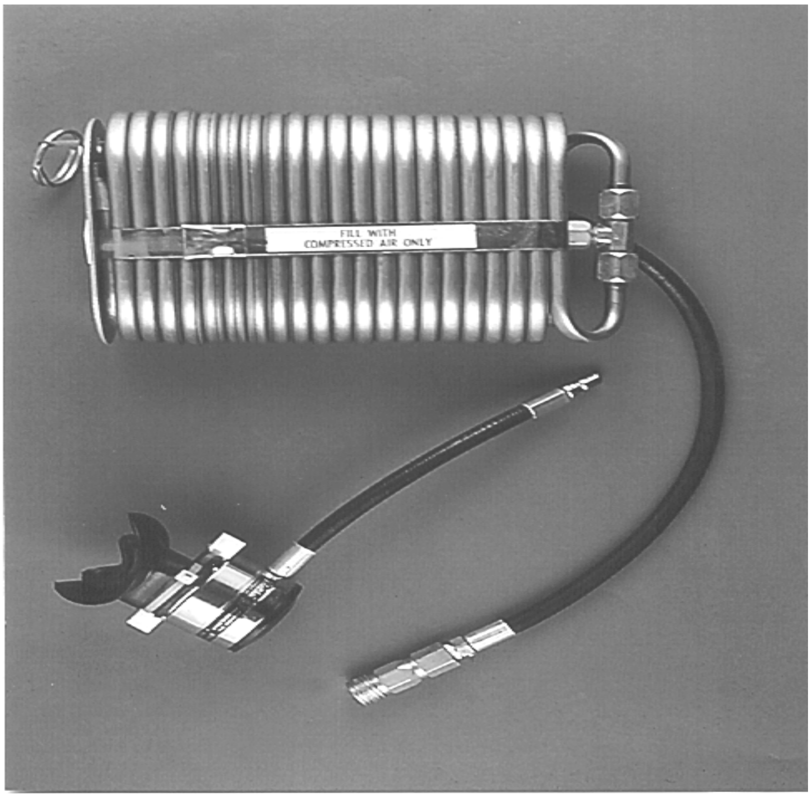

Figure 6a – The Robertshaw Controls Co. Unit.

Figure 6b – The Robertshaw Controls Co. Unit.
Unit is being demonstrated to show the bulk of the unit and impracticality of mounting on the lifejacket.

In 1981, Brooks identified a miniaturized compressed air breathing system made by Submersible Systems Inc. of Huntington Beach, California in a dive shop in San Diego, which he thought might represent an initial solution to the helicopter-ditching problem. (Fig. 2). The system was being used by commercial and sports divers as an emergency air supply. It consisted of an aluminum cylinder measuring 53 cm in depth by 5 cm in diameter and contained 56 litres of air pressurized to 1,800 psig. It included a single-stage suction demand regulator with a twist-turn on/off knob, rubber mouthpiece, purge button, pin-type pressure gauge and refill port attached to the head of the cylinder. The cylinder was US Department of Transport approved for repeat filling without needing hydrostatic testing. The minimum burst pressure was 6,000 psig and over pressurization was prevented by a brass disc, which bursts at 2,700 psig. The unit was available both in single or dual cylinder configurations.

The operation was simple. The rubber mouthpiece was placed in the mouth, either before or after the knob was rotated counterclockwise to open the bottle. The user either exhaled or depressed the purge button momentarily to clear the regulator of water. Breathing then proceeded through the demand regulator.

The Diving Division at DCIEM confirmed that it was an acceptable piece of equipment. In 16 test dives at 10 and 30 FSW with a moderate swimming workload, breathing duration was one minute and 18 seconds respectively from a single cylinder.

The MKI unit was then tested in the helicopter underwater escape Modular Egress Training Simulator at Survival Systems Limited, Dartmouth, Nova Scotia. The results confirmed that it worked in this scenario. The Sea King aircrew suggested that with the addition of a flexible hose, it could be stored in their survival backpack. Subsequently, Submersible Systems Limited modified their units (Mk2) to these specifications. In 1985, 10 MKI units and eight Mk2 units were successfully trialed in CFB Shearwater, Nova Scotia (Figures 2 and 3).

In order to fit the Mk2 units in to the Canadian Sea King aircrew's backpacks the following modifications were made: the high pressure hose was shortened by 13 cm to 47 cm; a swivel-type mouthpiece was provided; and the pin gauge contents indicator system was replaced with a small dial gauge. Progress continued slowly because several airmen in the operational approval chain were not enthusiastic about introducing the system into service. However, it was finally approved with the newly designed slim-line backpacks in January 1988. A one-day, practical pool training program was also introduced, in order to bring it safely into the Service. It then took the remainder of the year to introduce it into the fleet. It thus took a staggering eight years to introduce a piece of already well-proven equipment, requiring only the tiniest modifications into service!

In 1994, following several complaints about units becoming unserviceable due to poor regulator performance and low operator confidence with the system, the Canadian Air Force looked to replace their HEED Mk2. The principal author was involved in every step of this tortuous path. The lessons to be learned from this experience: if you wish to introduce a new system into service, is that you must be very determined, very persistent, continuously make your case based on good scientific data, and never give up in spite of all adversity! The Life Support Equipment Group at DCIEM conducted a preliminary laboratory evaluation on five new units in October 1993 (30). The systems tested were:

1. EMERG (LALSIP USA, Inc.)
2. HEED III (Submersible Systems Inc.)
3. Helicopter Emergency Egress Device HEED (Adams Rite Sabre) (Figure 7)
4. U.E.M. (Life Support Engineering Ltd.) (Figure 8)
5. Instantair - Emergency Breathing System (Lifeguard Equipment Ltd.) (Figure

From this evaluation, only the HEED III and the Adams Rite Sabre were recommended for further investigation.

In 1994, five systems were practically evaluated at Survival Systems Limited, Dartmouth, Nova Scotia (43). These systems were:

Figure 7 – Helicopter Emergency Egress Device Rite Sabre

1. HEED III (Submersible Systems Inc.)
2. Instantair (Lifeguard Equipment Ltd.)
3. HEED (Adams Rite Sabre)
4. ABLE 2000 (L.Adams Ltd,. UK) (fig. 8 a and b)
5. Survival Air System SAS (Meggitt Oxygen Systems, UK)

The functions examined were: the contents gauge, system arming, the purging device, purging quality, number of purges necessary, breathing resistance, comfort of the mouthpiece, and overall subject confidence. The results of the ratings from these examinations are listed in Table 4. It was concluded that the L. Adams ABLE 2000 was the most acceptable choice.

Figure 8a – L. Adams Ltd., ABLE 2000 MK1

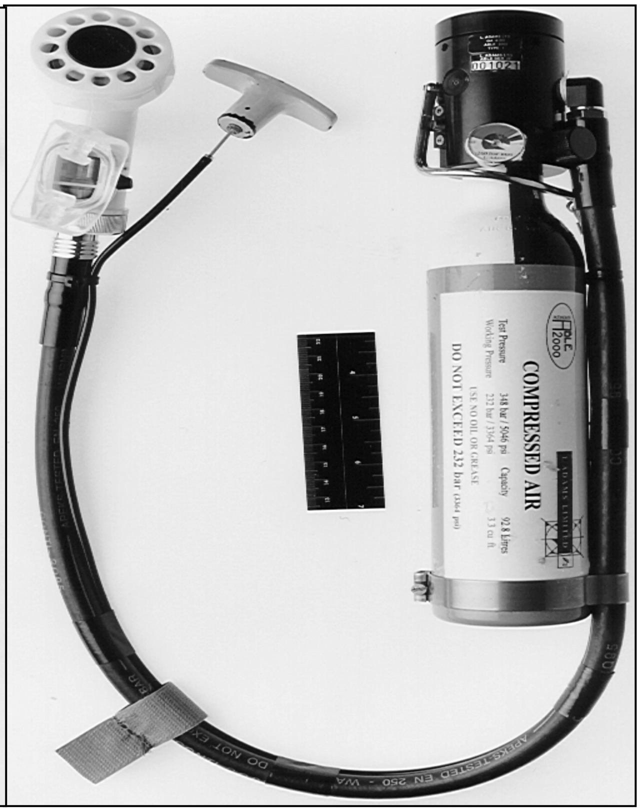

Figure 8b – L. Adams Ltd., ABLE 2000 MK2

Figure 9- A collage of six EBS Units tested at DCIEM in Toronto:

Top Centre: U.S. Divers Inc. MAS, SRU-40/P.
Top Right: Meggitt Oxygen Systems SAS
Centre: Unknown
Left Side: Life Support Engineering Ltd. Underwater Escape Module (UEM)
Bottom Middle: Submersible Systems Inc., Type I
Bottom Centre: L. Adams ABLE 2000 MK1

Evaluation Item	ABLE	SAS	HEEDS III	Instantair	HEED
Contents Gauge (/5)	4.2	3.5	4.0	0	3.0
System Arming (/5)	3.9	4.5	n/a	4.5	2.5
Purging Device (/5)	4.8	4.6	4.5	4.6	2.0
Purging Quality (/10)	9.2	8.3	7.5	10	5.5
No. of Purges	1	1.1	1.2	n/a	3+
Breathing Resistance (/10)	9.5	8.0	8.3	3.0	6.5
Comfort of Mouthpiece (/5)	4.4	4.4	4.3	4.0	4.0
Overall Confidence (/10)	8.6	8.3	8.3	3.7	3.0

Table 4 – Various human factors parameters evaluated on the 5 EBS during the Canadian Trials in 1993.

In the meantime, the U.S. Navy (31, 54) had tested and approved a new unit from US Divers Inc., (Figure 5) called the Micra Air System (MAS). This had not been available for the Canadian evaluation. It was decided to evaluate this system against the top two contenders in the previous trial - the L. Adams ABLE and the Meggitt SAS (59).

The Canadian evaluation of each system was conducted in three phases. The first phase was the examination of the air endurance and breathing regulator using a breathing simulator. For this, three units of each EBS were tested under four conditions - in 2 and 10°C water each at 2 and 10 metre depths. Maximum Respiratory Minute Volume (RMV) values (the total amount of new air moved into the respiratory passage each minute) were recorded by testing the EBS to the point where the absolute pressure required to inhale or exhale exceeded 2.5 kPa. (Figure 10) Divers then examined aspects such as ease of operation, purging capabilities, and recharging characteristics. A total of 5 dives was completed on each unit.

In Phase 2, the compatibility with current aircrew equipment was examined pre-flight; the ergonomics of the unit on normal cockpit post-flight, aircrew in-flight emergencies and ground crew bottle recharging (43). This was followed by Phase 3, in which two crews examined the practical problems of underwater escape: one pilot, one navigator, and one Airborne Sensor Operator. They conducted a series of underwater escapes from a helicopter underwater escape trainer from their representative positions in the helicopter.

The Meggitt SAS system could not be mounted on the back of the Mustang life preserver / survival vest. This “over the shoulder” configuration was a requirement of the replacement system. The company indicated that the system would not be redesigned, so it was eliminated from further testing. Ultimately, the U.S. Divers Inc. MAS system was chosen over the L. Adams ABLE system due to superior RMV values (Figure 9) and because, overall, it was favored by the aircrew, primarily because its operation only occupied one hand (59).

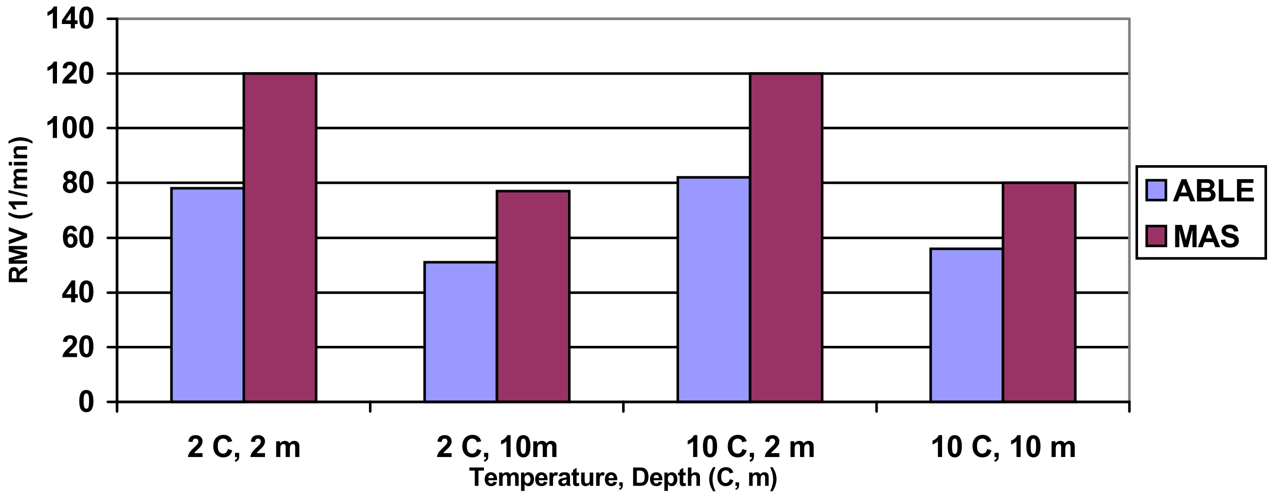

Figure 10 – Average EBS Respiratory Minute Volume (RMV) at Two Water Temperatures and Depths.

2.5 Progress in the rest of the world

It is known that the Italian Navy have been flying with an emergency breathing system made by Cressi since at least 1989. More recently Mercury Products (South) Ltd. in the UK have developed their Underwater Escape Module (UEM) system one step further, and this is being used by pilots of maritime helicopters in Singapore and New Zealand. Otherwise there has been little further progress.

2.6 The question of whether to train or not?

Training

HUET training takes place in water at or above 20°C; this explains why students, who are provided with well maintained "dry" suits for their training, come away from that training talking of disorientation and in-rushing water, rather than cold. It also helps to explain why a compromised capability to breath hold has not been quite the issue it should have been. Some experience of cold (a hand immersion for example) during such training will help to ensure that students respect the threat of cold water and, consequently, do all that they can to maximize their protection against it.

Whilst the need for some form of EBS has generally been accepted, there has been continued resistance to the need for in-water training in some quarters. Thus, some of those organizations that have introduced EBS have opted for "dry" rather than in-water training. In many cases the rationale for this position is the same as that used to argue against the introduction of EBS in the first place, and relates to the perceived dangers, logistic requirements and costs. As concluded in the CAA review of helicopter offshore safety and survival, "*Of the 30,000 or more individuals requiring training only a minute proportion would ever need to use the device in a real emergency, making even a small training risk unacceptable*."

No direct comparisons have been made of the comparative value of "dry" and "wet" EBS training for subsequent in-water use. Such a comparison should be undertaken as an important first step in establishing a valid and defensible training regime. In 1997, as part of a study in which they compared two concepts in EBS, a simple re-breather and a source of compressed air, Tipton et al trained naïve subjects in their use in air then water. They conclude: "*the*

performance of both devices is significantly improved by in-water training. This is primarily because it gives the opportunity for individuals to get used to the combined stresses of using a new piece of equipment and performing a helicopter underwater escape". This statement suggested that simple design will not "alleviate" the need for in-water training.

The idea that an individual who has received only training in air will then be prepared to use their EBS for the first time in water during a ditching in freezing cold water is counter-intuitive. There is a pressing need for the real benefit of dry training in the use of EBS to be determined, so as to ensure that the life saving potential of an essential piece of survival equipment is being maximized rather than negated.

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CHAPTER 3

Current Available EBS on the Market

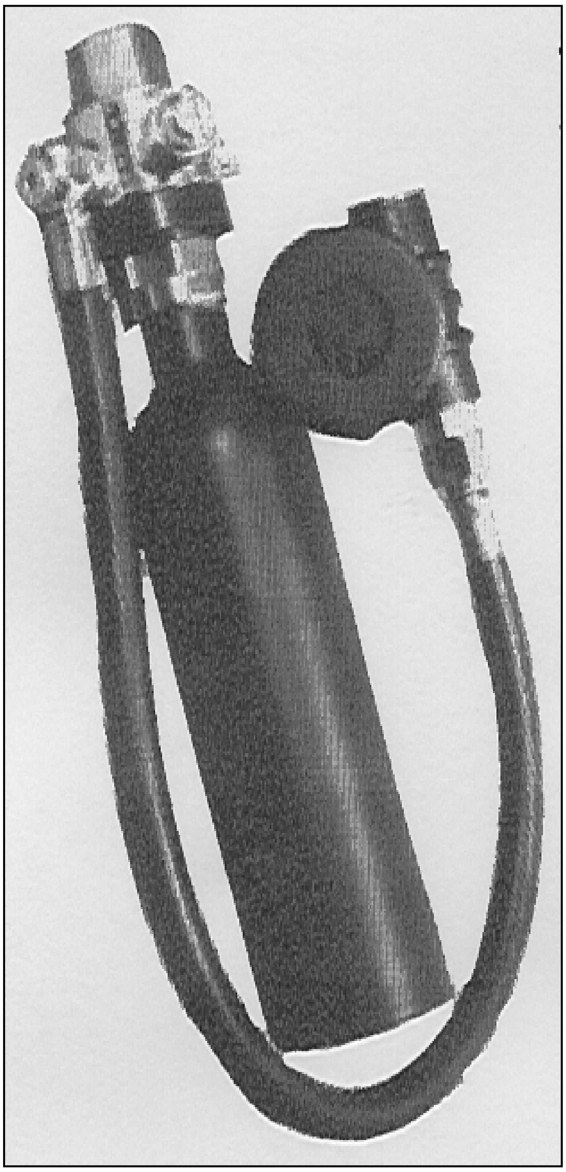
In order to assist NATO & PfP nations and civilian organization in procuring an EBS unit, a list of current manufacturers with unit specifications are presented as shown in their sales literature. This is being published with their approval:

3.1 AQUA LUNG

AQUA LUNG®

AVIATION LIFE SUPPORT EQUIPMENT

HABD



- HABD SRU 40 B/P
- Approved for use by the U.S. Navy
- Designed for use by helicopter crew during an emergency water landing
- Allows the user to have the regulator in mouth and both hands free for maneuvering
- Compact and lightweight
- Two stage design from proven Aqua Lung scuba regulator specifications
- 0078 approved

SPECIFICATIONS:

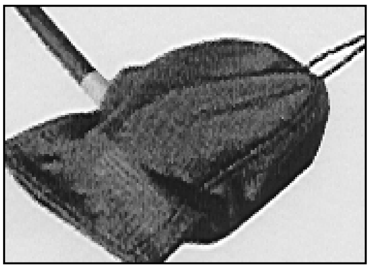
Part Number	1028-00
Cylinder Volume	1.5 cu. ft./42 liters @ 3000 psi
Floatable Volume	(13 cu. in./0.215 liters)
Cylinder Material	Aluminum
Cylinder Pressure Rating	3000 psi (205 bar)
Cylinder Length w/ reg.	10.5 inches (26.67 cm)
Low Pressure Hose Length	24 inches (61 cm)
First-stage Connection	360 degree swivel
First-stage Regulator	Modified Conshelf
Second-stage Regulator	Modified Micra
Pressure Gauge	Integral with first-stage
Operational Temperatures	+155° F/ +68° C > -25° F / -32° C
Pressurized Storage Temperature (closed)	65° F / -54° C
System Weight	2.5 pounds (1.13 kilos)
Buoyancy Full	-1.9 pounds (-.85 kilos)
Duration of Air Supply	Approx. 15 breaths at 33 feet (10m)

40 Cousteau Ct. Vista, CA 92083. TEL 760-597-5000. FAX: 760-597-4900. www.aqualung.com

AVIATION LIFE SUPPORT EQUIPMENT

QRC

2nd stage deployed

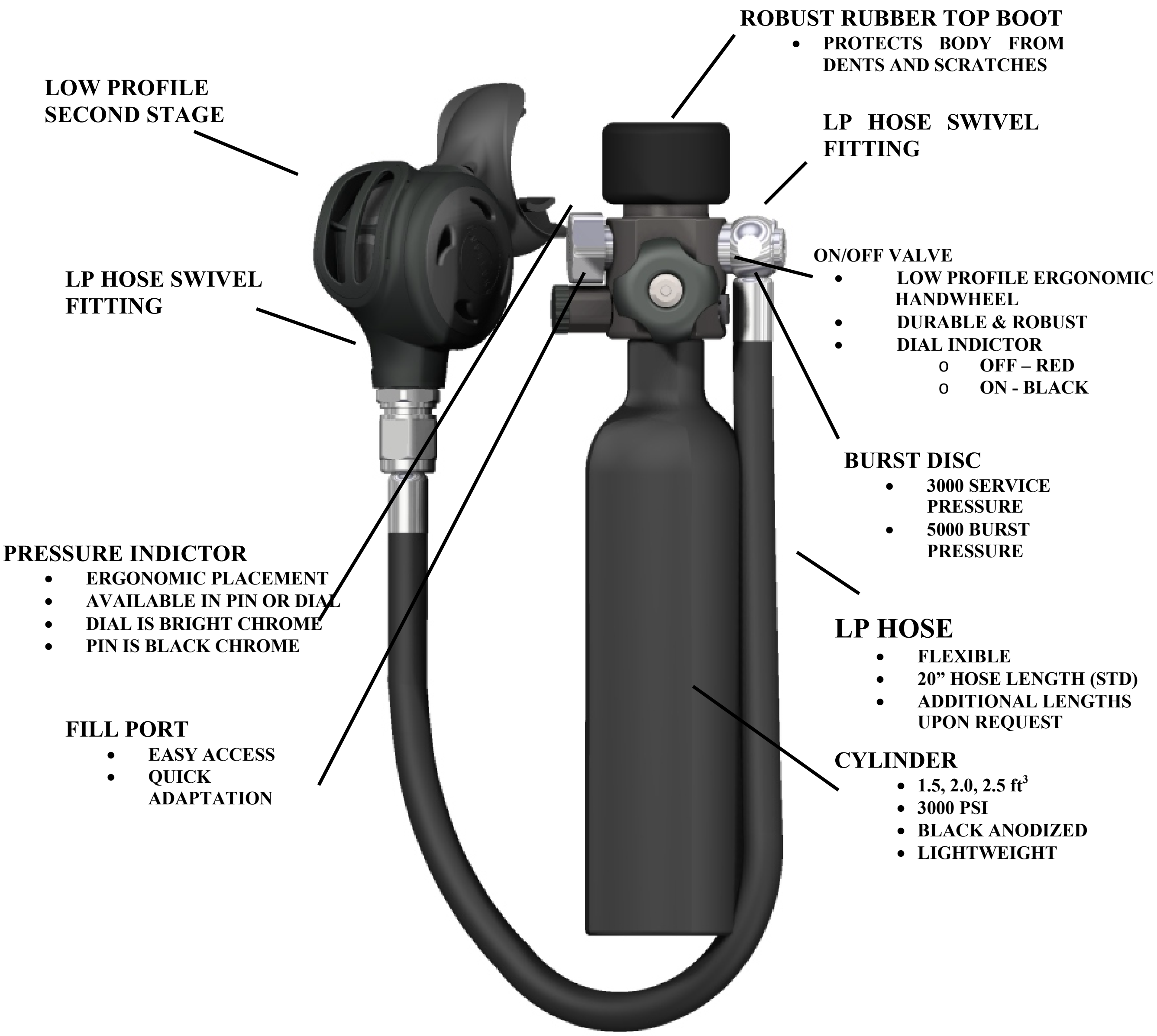


2nd stage non-deployed

- Quick Release Cover for the HABD SRU 40 B/P
- Choice of 2 color options
- Quick Velcro release allows for immediate deployment of the 2nd stage regulator
- Soft nylon cover protects against rotor wash operational, and operational and environmental conditions
- Attachment by a lanyard or sewable for hard mounting on the vest
- Part # 1007-94 – Black Nylon
  1007-96 – Woodland Cammo

(Lanyard and mouthpiece cover not included)

AQUA LUNG®



Design and Features Illustration
SEA MK 2.0

3.2 Kidde Graviner Ltd.

ABLE 2000 – STASS

ABLE 2000 is a new generation of short term air supply system (STASS) designed for underwater breathing when escaping from a submerged helicopter. The ABLE 2000 is a hands free system, which allows the user to have both hands available for manoeuvring when escaping from the submerged helicopter.

ABLE 2000 – STASS is lightweight, easy to refill and a compact system which fits onto the flight jacket via an integral pocket or attachment. It is a self-contained system which integrates a first stage regulator, and a second stage sub-aqua mouth-piece with regulator and a lightweight aluminium cylinder.

ABLE 2000 – STASS SPECIFICATION		
Part no.	GA 5380	GA 5390
Cylinder capacity @ 232 bar	92.8 litres	46.4 litres
Cylinder Material	Aluminium	Aluminium
ABLE 2000 length with Regulator	300 mm	235 mm
Rate Cylinder Pressure	232 bar	232 bar
Medium Pressure Hose Length	390 mm	390 mm
Second Stage Regulator	Oceanic Slimline	Oceanic Slimline
Pressure Gauge	Yes	Yes
Safety Device	Bursting Disc	Bursting Disc
Weight with Second Stage	1.1 Kg	0.8 Kg
Depth Rating @ 90 lpm Ventilation Rate (breathing rate of 36 bpm, volume 2.5 litres)	16.4 msw (54 fsw)	16.4 msw (54 fsw)
Depth Rating @ 62.5 lpm Ventilation Rate (breathing rate of 25 bpm, volume 2.5 litres)	28.9 msw (95 fsw)	28.9 msw (95 fsw)

Kidde Graviner Ltd
Mathisen Way, Colnbrook, Slough ,
Berkshire, UK
Telephone: +44 (0)1753 683245
Facsimile: +44 (0)1753 685126

3.3 MSI Defence Ltd.

The P-STASS won a MoD competitive tender for a passenger helicopter escape device. The unit was developed from a driving outlook as opposed to standard helicopter safety equipment.

The cylinder is a 0.4 litre capable of being charged to 232 bar. This is linked to a miniature 1st stage regulator giving a diving pressure of approx 9 bar to the integral second-stage regulator and mouthpiece.

The design criteria requested a duration of 2 minutes at 5 metres. But this is a meaningless figure as there are so many other dependencies, e.g. panic, experience, physical build etc.

The performance of the equipment is capable of 50-metre diving but the cylinder obviously is not. The cylinder size in this case was a compromise to meet optimum performance and still fit within the existing flying clothing.

To date, trials are still being conducted. Environmental, all noxious fluid contamination, fitting and integration into various helicopter types, using both experienced and naïve subject.

On completion of the trials, expected December 2000, the production order of 3,500 will be released.

MSI Defence Systems Ltd.
10 Cambridge Road
Granby Industrial Estate
WEYMOUTH, Dorset, UK, DT4 9XA
Telephone No. +(44) 1305 760111, Fax. +(44) 1305 76022
E-mail: msidefw@dial.pipex.com

3.4 MEGGITT AVIONICS

HELOSCAPE addresses the specific needs of an untrained passenger whilst escaping a submerged helicopter. The device provides several innovative patent features and takes a different approach to other escape apparatus.

The design is built on the basic assumption that the user will be very inexperienced with breathing equipment and it must therefore be as simple as possible to bring into use. HELOSCAPE achieves single action deployment by using a unique watertight mouthpiece and nose occluder. This removes the need for wearers to purge and also automatically blocks the nostrils to prevent nasal inhalation, even when inverted. Breathing air is supplied through a two-stage regulation system at a high flow rate, based on the guidelines of the Norwegian Department of Energy.

Key aspects include:

- Single Action Deployment
- Watertight Mouthpiece Enables a Dry Air Supply
- Wide Anthropometric Suitability
- Automatically Occludes Nostrils
- Two Stage, Balanced, High-Flow Regulator System
- Optional Cylinder Sizes
- Cylinder Contents GO/NO-GO Indicator

For more information on HELOSCAPE please contact:

MEGGITT

Meggitt Avionics (Oxygen Systems)
Whittle Avenue, Segensworth
Fareham, PO15 5SH, UK
Tel: +44 (0)1489 483300
Fax: +44 (0)1489 483340

3.5 MERCURY PRODUCTS (SOUTH) LTD.

MERCURY PRODUCTS (SOUTH) LTD

Underwater Escape Module (UEM)

UEM UNIT	(GA No. 200480-00)
Length	293 mm
Weight	1.15Kg (Tare Wt Approx)
Free Air Capacity	80 Litres
REGULATOR	
Material	Chrome Plates Brass
Working Pressure	9.6/10.3 bar (140/150psi)
Gauge Graduation	Pointer should be in green section when fully charged
Type	Constant Reading
CYLINDER	
Specification	BS 5045 pt. 6
Working Pressure	200 Bar (2900 psig)
Test Pressure	300 Bar (4354 pisg)
Neck Thread	M18 x 1.5mm
Material	Aluminium Alloy 6061
Water Capacity	0.40 Liters
Length	244mm
Diameter	60mm
DEMAND VALVE	
Downstream Valve	
Type Purge Flow	>=20 Litres/minute(l/m)
Inhale resistance	
(full Cylinder pressure)	<=89mm WG@50l/m (3.5 inches WG)
Exhale resistance	
(full Cylinder pressure)	<=152mm WG@50l/m (6.0 inches WG)

OPERATION

The UEM KM4, mounted in the lifejacket, is immediately ready for use. The Demand Valve is removed from the regulator and placed in the mouth. Air is ready for inhalation. If this is done underwater the normal purging procedures are carried out.
Once this unit has been used it should be returned to base for checking and refill.

MERCURY PRODUCTS (SOUTH) LTD

Mercury House 36 Carpenters,
Billingshurst, Sussex, RH14 9RB
England.
Tel. 44+(0)1403 782760 Fax. (0)1403 786637
E.mail bir@lifesupport.freeserve.co.uk

3.6 THE SHARK GROUP

AIR POCKET AND AIR POCKET PLUS HELICOPTER EMERGENCY UNDERWATER BREATHING SYSTEMS

The Shark Air Pocket and Air Pocket Plus Helicopter Emergency Underwater Breathing Systems have been developed to combat the effects of Cold Shock and provide additional escape and survival time. They are the end result of a 500,000-pound research project funded by Shell Expro and Esso, which involved Shark Group's expertise in the design and manufacture of breathing systems with leading physiologists from the Robens Institute of Health and Safety and the Institute of Naval Medicine.

In a ditching emergency, the helicopter often inverts because it is top heavy, and the immersion victim has to contend with disorientation, panic, confusion, poor visibility and Cold Shock, which can drastically reduce breath-hold times. Best estimates indicate that 40 to 60 seconds are needed to make a successful underwater escape, but independent tests in 10 degree C water have shown that average breath-hold times are between 17 and 30 seconds.

The original **Air Pocket** is designed to enable the immersion victim to re-breath the air in his or her lungs or immersion. It is a counter-lung integrated into the survival suit and is used un-primed.

Air Pocket

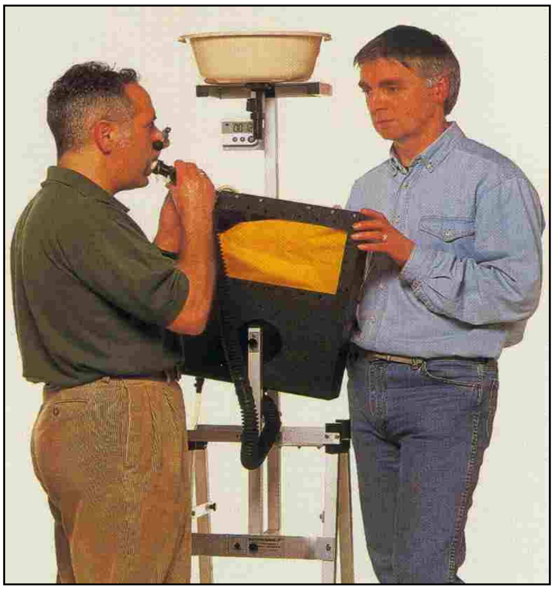
- Is safe and easy to use.
- Has a low training requirement.
- Has a calming effect.
- Can be used in any orientation underwater.
- Helps overcome disorientation.
- Requires minimal maintenance.
- Is approved UK Civil Aviation Authority non-hazardous accessory.

Air Pocket came into service in 1996 and is well proven, with 6000 in daily use in the challenging environment of the UK North Sea Sector.

Air Pocket Plus is a second-generation development, which builds on the experience and strengths of the original Air Pocket and provides further benefits to the user. Air Pocket Plus has been tested by Cranfield University.

Air Pocket Plus

- Is simple to use.
- Delivers a charge of clean air automatically on immersion.
- Makes a breath of air available even if there was no chance to breath-hold before immersion.
- Is light and compact, fitting between the lifejacket lobes.



Can be used with all existing survival suits without modification.
Has no maintenance requirement for 5 years unless used in an emergency.
Simple 5 year maintenance before returning to service for another 5 years.
Has low training requirement.
Manual version available.

Air Pocket Plus has been designed to minimize the risk of cerebral arterial gas embolism, which results from any system which introduces supplementary gas. The breathing bag is generously sized to contain the air charge plus any breath from breath-hold, without producing over-pressure.

Shark Group's Design Team has had the benefit of the in service experience and customer feedback from Air Pocket and the extensive naïve subject trials for Air Pocket Plus, conducted by Cranfield University, which has been incorporated into the design and operation of Air Pocket Plus.

The Shark Air Pocket Dry Trainer has been developed to enable trainees to experience the hydrostatic pressure which would be experienced when using Air Pocket and Air Pocket Plus in various positions underwater, without the trainee getting wet. It is flat packed in an air transportable case, ready to assemble wherever training is needed – in heliports, in training establishments or on offshore installations. The Air Pocket Vest has also been developed for training purposes.

Air Pocket and Air Pocket Plus are Millennium Products, which have been recognized by the UK Design Council as two of the most innovative products for the 21st Century. They are covered by international patents.

Shark Group has 35 years of experience in the design and manufacturer of apparel for challenging environments, and more than 20 years experience in the design and support of survival and emergency breathing systems. It has been consistently innovative, developing market-leading solutions to the challenging problems of surviving a helicopter ditching at sea.

Shark Group
Nordstrom House, North Broomhill, Morpeth, Northumberland, NE65 9UJ, UK

SHARK GROUP

NQA ISO 9001 REGISTERED COMPANY

Phone 0044-1670 760365
Fax 0044-1670 761343
Email sales@sharkgroup.co.uk
Website: www.alnmarin.co.uk/shark and www.offshore-technology.com

3.7 SUBMERSIBLE SYSTEMS INC.

Submersible Systems, Inc.
18072 Gothard Street, Huntington Beach California 92648
(800) 648-3483, (714) 842-6566

The Helicopter Emergency Egress Device (HEED) manufactured by Submersible Systems, Inc. is a compact lightweight breathing system designed to enhance the survivability of aircrew and shipboard members. This miniature self-contained breathing apparatus protects aircrew members from the dangers of drowning due to ditching an aircraft into the water, and also protects shipboard members from inhaling dangerous and lethal toxic fumes of an engine room fire.

All armed forces inn the United States who utilize helicopters have incorporated the HEED as a part of their safety equipment since it was first deployed in 1984. The Navy has incorporated the HEED renamed for this application SEED (Supplementary Emergency Egress Device) into use by all shipboard engine room personnel as part of their safety equipment. This product is also being used by military personnel throughout the world, including such countries as England, Canada, Australia, Spain, and Brazil. To date several dozen lives have been saved and many more had reduced injuries due to the use of this product.

Worldwide use of the HEED system has created a demand for several variations to the original HEED model. Submersible Systems, Inc. has successfully customized the HEED on several occasions to fit the needs of our customers. Submersible Systems. Inc. will stay on the leading edge of the survival equipment industry by continuing to listen to our customer's requirements and to provide them with the latest, most technologically advanced equipment available.

The HEED consists of a single stage balanced regulator attached to a 3000 p.s.i. DOT rated cylinder. It is 8 ¾" tall by 2 ¼" in diameter and weighs only 1 1/3 pounds. HEED III includes a one-way check valve that enables the system to be on demand and ready for use at all times as well as making the HEED very easy to refill from either an air compressor or from a scuba tank. The HEED is small enough to fit into most pockets already included on a flight vest. Upon specific requests from our customers, Submersible Systems, Inc. has developed a holster that can either be sewn onto a vest or worn on a belt.

HEED is offered in various models based on the users preferences:

HEED III 175M – This system was the first version of the HEED III models. It has a fully activated purge button (can be manually activated by a finger) that is used with the expectation of easier purging ability. Users must be willing to accept the possibility of tampering and increased need for refilling because personnel may activate the purge, releasing air accidentally or out of curiosity. A pin-type pressure indicator is included that allows for limited (full or ½ full) air pressure readings at a glance.

HEED III 175 T-H – This model was designed upon requests of several users for more accurate pressure readings, less possibility for tampering and reduced maintenance requirements. It includes a dial gauge pressure indicator that allows for more accurate pressure indication from p.s.i. to 3000 p.s.i.. The dial gauge was incorporated to assist in more rapid determination for refill requirements. This model also includes a non-activating hard cover to prevent tampering

which may cause an unnecessary loss of air. The hard cover reduces maintenance, the need for refilling and time spent on training personnel due to the elimination of the need to manually purge the system before use.

STANDARD REFILL ADAPTERS 920M – This adapter is used to refill the HEED from an air compressor capable of filling to 3000 p.s.i..

SPECIAL REFILL ADAPTER 910CM – This adapter is designed to allow the user to refill or Top Off the HEED directly from a 3000 p.s.i. scuba tank.

REFILL SYSTEM 3500-100 (TRS3500) – This is a complete portable system designed to refill 6 to 8 HEEDS before having to refill the main scuba tank. The TRS3500 includes a 3500 p.s.i. scuba tank with a refill hose assembly and a pressure gauge, all surrounded by a protective cage.

HOLSTER 957V-MP - The holster provides easy accessibility to the HEED and can either be worn on a belt or sewn onto a flight vest for every secure attachment. It includes a protective mouthpiece cover to prevent contaminants from entering the mouthpiece of the HEED. The mouthpiece cover is attached to the holster with a thin cable lanyard so that it is not lost when pulled from the HEED during use.

SPECIFICATIONS		
	HEED III Mod.1	HEED III
Model No.	175 T-H	175M
Length (in.)	8.75	8.75
Diameter (in.)	2.25	2.25
Weight (lbs.)	1.3	1.3
Pressure (PSI)	3,000	3,000
Air Capacity (cu. ft.)	1.7	1.7
Surface Breaths	30	30
Valve Actuation	Check Valve	Check Valve
Pressure Indicator	Dial Gauge	Pin Gauge

OPTIONS*

Cylinders (3,000 p.s.i.)	Regulator Cover	Pressure Indicator
1.7 cu. Ft.	Soft Purge Button	Pin Gauge
2.7 cu. ft.	Hard Cover	Dial Gauge

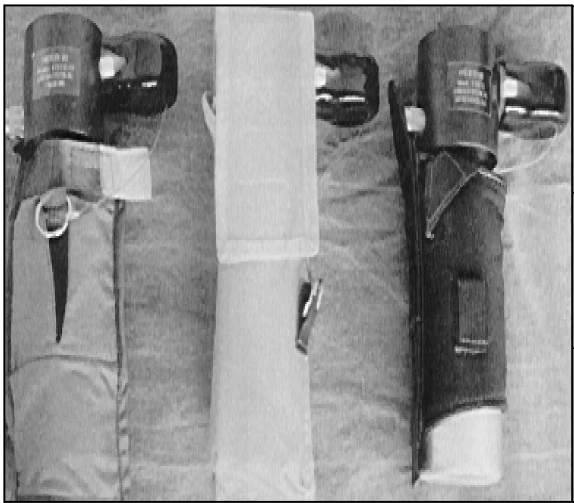
* Other options for specific requirements available upon request.

HEED

TANK REFILLING SYSTEM

18072 GOTHARD STREET, HUNTINGTON, BEACH, CALIFORNIA, 92648
U.S.A.
TELEPHONE 800-648-3483, 714-842-6566, FAX 714-842-4626

HEED III ACCESSORIES



957G-MP	957VC-MP	957V-MP
GREEN HOLSTER	YELLOW HOLSTER	BLACK HOLSTER

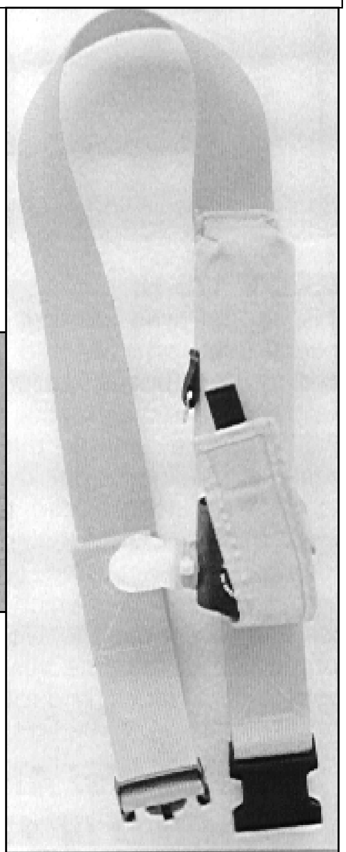
#957GR-MP
The lightweight green Nomex holster is designed for securing and easy access of the HEED unit on a vest, or belt. A Velcro pull-tab and interior elastic webbing help secure the HEED. Designed for the U.S. Army Survival Vest, but will work with others.

#957VC-MP
The yellow nylon covered holster provides easy accessibility to the HEED and can be worn on a belt or sewn/velcroed onto a flight vest. The nylon Velcro flap helps protect the Regulator, Check Valve, and Pressure Indicator from impact

#957V-MP
The black nylon holster provides easy accessibility to the HEED and can be worn on a belt or sewn/velcroed onto a flight vest. This is the holster supplied when you order the HEED unless one of the other holsters is specified.

All holsters include a protective mouthpiece cover to prevent contaminants from entering the mouthpiece of the HEED. The mouthpiece cover is attached to the holster with a thin cable lanyard so that it is not lost when pulled from the heed during use, inspection or cleaning.

#958USCG YELLOW BELT/HOLSTER COMBO
This 42” long 2” wide Belt/ Holster combination comes with nylon reinforced adjustable non-corrosive quick release buckle. The holster is mounted horizontally to maximize movement.



#920CM STANDARD REFILL ADAPTER
This Adapter is used to refill the HEED from an air compressor capable of filling to 3000 psi.

#910CM SPECIAL REFILL ADAPTER
This adapter is designed to allow the user to refill the HEED directly from a 3000 psi SCUBA tank.

SIMPLY DEPENDABLE

CHAPTER 4

Choosing and Integrating an EBS

4.1 Re-breathers vs Compressed Air/Oxygen Systems

EBS fall into three broad categories: re-breathers, sources of compressed air or oxygen; hybrid devices combining a re-breathing bag and source of compressed air or oxygen. For practical purposes devices in the last category can be regarded as sources of compressed air. There is no generic "definitive" answer to the question of which of the concepts is superior; this depends on the circumstances in which the device is used.

Some of the comparative positive and negative features often quoted for the two approaches are listed below. Some are fallacious or poorly considered – these are marked with a (?):

RE-BREATHER	
Positive aspects	**Negative aspects**
Simple	Danger of hypoxia
Introduces no additional dangers	Potential maximum duration around 90s
Minimal/simple training	Interrupted use not possible
Duration not influenced by hyperventilation	No bubbles released
More intuitive for the naïve user	Breathing resistance changes with orientation
Low maintenance	No purge capability
Cheaper	Requires an inspiration prior to use
	Complex mouthpieces (?)
	Increased buoyancy (?)
	Integration difficulties (?)
	Present a hazard at surface (?)
	More difficult to locate and use (?)

COMPRESSED AIR/OXYGEN	
Positive aspects	**Negative aspects**
Potential maximum duration 3-5 minutes	More expensive
More "high-tech"	More complex
Proven benefits in real accidents	Greater training need
Several devices available	Introduce additional dangers
Can breath-hold when unit runs out	Greater maintenance requirement
Purge capability	Depleted rapidly by hyperventilating user
	Integration can be difficult
	Poor regulator characteristics (single stage devices)
	Risk of discharge (single stage devices)

When choosing a system it is therefore important to establish: the performance objective (underwater survival time) required for the aircraft being used; the user population (e.g. aircrew, naïve passengers); the potential conditions in which the device may have to operate (cold, cool or warm water); and, critically, the other protective equipment being provided (type/quality of immersion suit, thermal undergarment etc.) i.e. the type and quality of the Integrated Survival

System being put together. The performance requirement demanded of the EBS will be inextricably linked to the quality of the other immersion protection provided. Other considerations will include cost, training logistics and time available for training.

It is clear that no approach will be the most appropriate for all combinations of the above. In some scenarios a re-breather will be the device of choice, in others a source of compressed air or oxygen.

In choosing a specific system, the following guidelines should be considered to ensure that it forms part of an integrated survival system, whether mounted in the cabin, the cockpit or on the aircrew or passenger.

4.2 Check the Credentials of the Chosen System

Having established the research and development work that has contributed to the production of the device (see Chapter II), it is a good idea to get a professional diver, or diving company, to review the specifications of the system, paying particular attention to:

- Air endurance of the system.
- The work of breathing under maximum and half pressure, which should not exceed 4.0kPa in the inspiratory or expiratory phase.
- The performance down to 4 atmosphere absolute of pressure.
- The RMV in litres / minute.
- The performance underwater in temperatures of 2°C and 15° C.
- Leak tests on the units.
- Decrease in bottle pressure over 24 hours.
- Successful operator bottle pressure release system.
- Ability to be operated with a single hand.
- The overall design of the system to ensure that there are no obvious inherent flaws that may come up from use, mishandling or servicing.
- Ease of recharging.
- If fitted into a fixed wing aircraft, it should be certified safe in the event of a decompression.

4.3 Integration into the Cockpit or Attachment to the Human

To date, the helicopter manufacturers have paid little attention to the integration of any form of air supply into the seat or fuselage. They have drop-down oxygen masks for fixed wing aircraft, but have ignored the problem for over-water helicopter crew and passengers. The attachment of a device to the human will be determined to a large extent by the nature of the device and other equipment being worn. As we have seen, compressed air systems tend to resemble a miniature compressed air diving system, and can comprise: a compressed air bottle; a primary and

secondary regulator; and a whip hose onto the front, back, or side of the human. The re-breather systems tend to have a mouthpiece adapter and some form of large plastic bag.

In locating the breathing aid, the following are amongst those other items that must be considered: the life jacket and webbing; other survival aids; seat harness; quick release fitting; summer and winter flying coveralls; a survival suit; and body armour. Other items that compete in the same space include the seat, the cyclic and collective helicopter controls, various potential snag points on the door / window frames and the console. It should be remembered that in the newer military helicopters, the crashworthy seat will stroke up to 10 or 12 inches on impact.

4.4 Choice of Site

Once the site has been chosen, a series of ergonomic tests must be conducted with the unit to ensure security on the body and ease of immediate access when inverted underwater (Figure 11). The mouthpiece must be easily placed in the mouth single handed and with minimum effort when strapped in. Other important features to be examined include, that:

- pre-flight checks on the bottle contents gauge or pin gauge can be conducted easily.

- the ON / OFF switch is easy to operate, there is no likelihood of the gauge being misread or the bottle being inadvertently switched off during air operations.

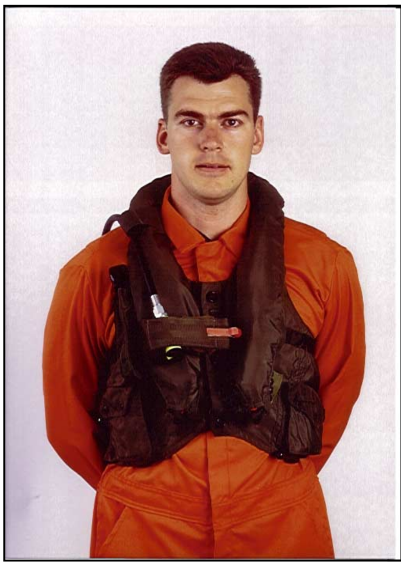
- the device can be worn with comfort in the helicopter for up to four hours at a time.

- the device does not physically interfere with the operation of cyclic, collective, or any levers or switches during normal or emergency operation.

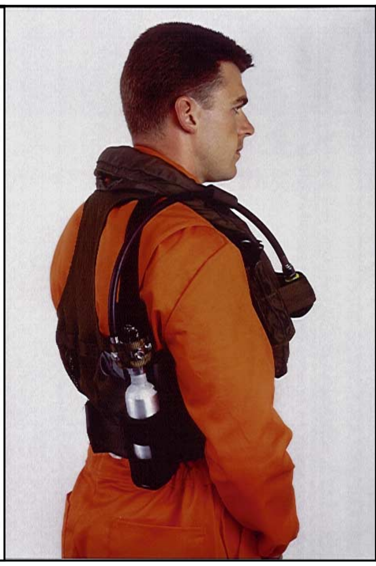
- the device does not visually obscure any critical light, gauge, or switch.

- the device does not interfere with normal or emergency strap-in procedures and egress procedures.

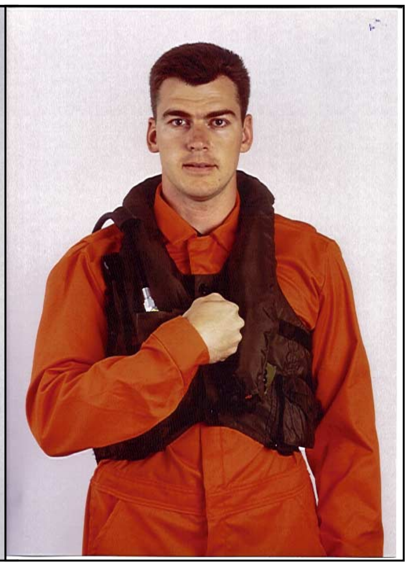
- the device does not create a snagging problem anywhere along the primary or secondary escape route out of the helicopter, both for emergency ground egress and underwater egress, with the seat unstroked or stroked.



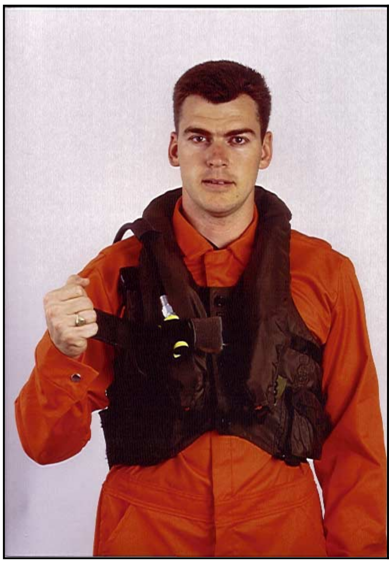
Front View of regulator neatly stowed in the pouch on the lifejacket.



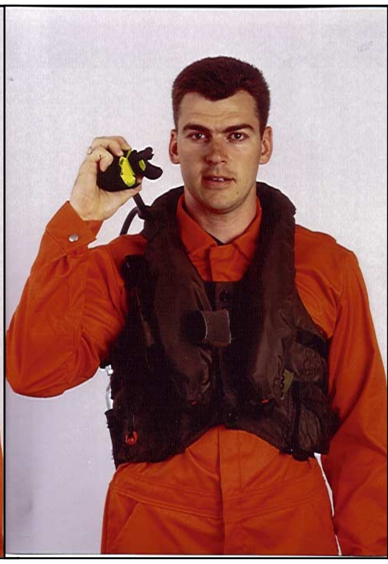
Rear view to show stowage of compressed air bottle on the back of the lifejacket and routing of the hose.



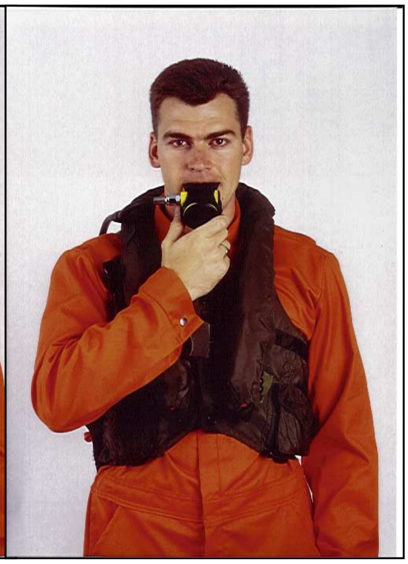
First action is to grasp the red toggle on the regulator retaining pouch



Second action is to pull open the pouch to reveal the body of the regulator.



Third action is to pull open the pouch to reveal the body of the regulator.



Fourth and final action is to place the regulator in the mouth and commence breathing from it.

Figure 11 – A typical basic evaluation of an EBS (U.S. Divers MAS) mated to a lifejacket (Dunlop Beaufort MK-15)

4.5 Practice Testing for Emergency Ground / Surface Evacuation

The next step is to individually strap in five male and five female subjects in the representative seats in a HUET. The anthropometric characteristics of the subjects should span the whole range of the aircrew and passenger population. The HUET is raised six feet over the water, and then lowered to the surface so the deck plates are just awash. An emergency surface evacuation is conducted from a) the pilot seat adjacent to a window; b) a pilot seat with a blocked window so that it is necessary to cross the cabin console and escape from the opposite side; c) each passenger / crew person seat in the fuselage using both the primary and secondary escape route for that helicopter. Once in the water and out of the fuselage, the subject must leave the system undeployed. They will inflate the life jacket and deploy a face shield (splash guard) if fitted on the life jacket, and then enter the liferaft. This will ensure that the system has been cleared for snagging for each escape path for evacuation, for safe inflation of the life jacket, and for safe entry into the liferaft.

4.6 Practical Testing for Underwater Egress

These same five male and five female subjects should then conduct a series of underwater escapes using the system from each of the representative seats through each of the representative windows in the helicopter underwater egress trainer. The same escape paths must be used as in the surface evacuations. Normal safety precautions will be necessary: the subjects will receive training in the use of the device in air and water; one instructor must observe each subject; and there should be a safety diver in the pool at all times. At the poolside, there will be the resuscitation equipment tested and available, and all instructors must be trained in CPR and First Aid.

Particular attention must be paid to:

- comfort, security on the body
- ease of locating mouthpiece
- ease of clearing regulator, if required
- ease of breathing through regulator
- problem with unstrapping
- problem with swimming/moving to exit
- any problems with snagging

If the results of all of these tests are satisfactory, the system can be approved for flight providing 1) a course training manual on how to train students has been written for the instructors at the base level; 2) a user manual has been written for the line pilots and operators of the equipment; and 3) a maintenance manual has been written for the life support equipment technician.

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CHAPTER 5

Guidelines for Training in the Safe Operation of a Helicopter Underwater Escape Emergency Breathing System

5.1 The Introduction of the Equipment to the Squadron or to Crew and Passengers of a Civilian Helicopter Operation

One of the worst things that can happen during the introduction of a new system is that a batch of brand-new emergency breathing systems arrive unannounced to the Safety Equipment Office, the Squadron Commanding Officer, the Chief of Flight Safety, or the Chief of Air Maintenance. Even worse is the fact that no one knows how to operate or service them, train with them, or introduce them into the service. The US Coast Guard were very cognizant of this potential problem and were very diligent in the introduction of their LPU-25/P Underwater Escape Re-breathing Device into their service. An excerpt from their Manual is reprinted below with the permission of the Commandant (G-OAV-3), Aviation Life Support Division; and is an excellent example of how to introduce a new item of life support equipment into a helicopter fleet.

5.1.1 EXCERPT FROM US COAST GUARD MANUAL

Underwater Escape Re-breather Training

This outline is designed to provide a lesson plan for minimum aircrew training, which must be completed in order to comply with requirements in Coast Guard Air Operations Manual (COMDTINSTM3710.1A) prior to flight with the LPU-25/P survival vest.

The LPU-25/P incorporates an Underwater Escape Re-breather device within the survival vest and may be referred to as the UER. Suggestions or comments to improve this training are encouraged.

Underwater Escape Re-breather Vest Training
- Classroom Briefing Phase

1. *Overview*. This phase of the training may be conducted in a classroom. All of the information provided in this lesson outline must be presented to personnel receiving required training on the LPU-25/P vest. The presentation format may include videotape or slide programs, as well as lectures.

2. *Documentation.* Have each person sign in to document training. Upon completion of both the classroom briefing and the in-the-water training, an individual training jacket entry will be made including the date of training and instructor.

3. *Show videotape.* “Two Minutes to Life” if available.

4. *Why have a re-breather vest?* In the past, several Coast Guard helicopter accidents occurred in which aircrew members survived the initial impact, but were unable to successfully egress the aircraft when inverted in water. The US Navy developed the 9D-5 Underwater Egress Trainer to teach aircrew standard procedures for survival in such situations. The 9D-5 egress training has significantly reduced the fatality rate associated with ditching.

   The gasp reflex. Researchers have discovered that people who can hold their breath an average of 103 seconds in room temperature air, average only 12 seconds maximum breath holding time during initial immersion in cold (50 °F) water. This involuntary gasp reflex provides substantial reduction in the margin for error if aircrew during egress encounters difficulties. The UER was designed to expand that margin for survival.

5. *Hazards*. There are hazards associated with the use of any equipment. Your single, most important survival tool is **you**. The UER may be dangerous in untrained hands.

   a. Buoyancy. The Coast Guard has run numerous egress tests in the 9D-5 Egress Trainer with personnel wearing both the anti-exposure coverall and inflated UER. With that combination, the buoyancy exceeded 40 pounds and there was no significant difficulty encountered when normal, hand-over-hand, egress procedures were used. However, with the buoyancy from the inflated UER and anti-exposure garments, one does float up if reference points are lost. With the two minute breathing supply provided by the vest, there is time to re-establish reference points and pull (not swim) out of the aircraft.

   b. Embolism. Water pressure (when submerged to depths as little as three feet) compress air in the lungs. If you breathe additional compressed gas at depth, you create a potentially hazardous situation. As you return to the surface, the compressed gas will expand and you should let it escape by exhaling. If you don't exhale, the gas will expand into unusual places, maybe into the blood stream. Bubbles in the blood may cause convulsions or even death.

      This problem is compounded with the more rapid ascent associated with wearing a buoyant device.

      ALWAYS EXHALE DURING ASCENT WHEN BREATHING ON THE UNDERWATER ESCAPE RE-BREATHER VEST!

      Symptoms include:

      - Pain in chest
      - Impaired motor skills
      - Difficulty in breathing or swallowing

      Treatment includes:

      - Keep victim lying down.
      - Elevate legs, lower head.
      - Administer pure oxygen.
      - Transport to nearest qualified medical assistance, and, specifically and very important, report to the doctor that the student has been breathing compressed air and may be suffering from the results of this.

Any survival vest, which has a closure channel in the center front, may channel water to the face, given the right sea state and orientation. To avoid this problem, turn 45 degrees or more away from the seas and you will increase your survival time.

6. *Vest Familiarization*. Have one of the trainees don vest and adjust straps. Point out features and demonstrate operation.

- Point out that loose adjustment of straps may result in the vest twisting in the water when inflated, reducing visibility and chances of egress.
- The new vest is made from an Aramid (Nomex) fire retardant fabric shell. The old vest was nylon.
- The new vest will self-right an unconscious person. The old vest did not.
- Pre-flight. Review pre-flight procedures (see paragraph 7).
- Locate oxygen inflation toggle by feel. Go to bottom of zipper. Feel along bottom of left lobe until toggle is located.
- Pull toggle to inflate oxygen portion of vest.
- Locate oxygen breathing tube by feel starting at bottom left of bladder.
- Insert mouthpiece in mouth and carefully open valve. Note: The pressure in the bladder may cause a rush of air into lungs if unexpected. Vent excess around edges of mouthpiece and breathe cautiously.
- ALWAYS close mouthpiece valve before removing from mouth.
- Demonstrate features, feel and operation of mouthpiece valve. Caution: Do not pinch fingers with base of valve when closing.
- Close mouthpiece valve.
- Locate and demonstrate operation of CO_2 side oral inflation tube.
- Locate CO_2 inflation toggle by feel starting at bottom right of bladder.
- Inflate CO_2 side of bladder by pulling CO_2 inflation toggle. Note the escape of excess gas through the pressure relief valve.

7. *LPU-25/P Pre-Flight*.

- DO NOT OPEN VEST DURING PRE-FLIGHT INSPECTION.
- BY FEEL, confirm that the oxygen bottle is in place. Note: Opening the vest and removal of the bottle for pre-flight checks will shorten life of seal, which bottle screws against, thus it may possibly cause failure during inflation. A life support professional packed your vest; leave it that way.

- BY FEEL, confirm that the breathing hose is routed outboard of the oxygen cylinder and inflator.

- BY FEEL, confirm that the mouthpiece valve is closed.

- Ensure that oxygen inflation pull toggle is readily accessible (extending below the protective cover).

- Inspect the attached equipment in pockets for proper location and quantity.

8. *Revised Egress Procedures*. Note: These procedures will be incorporated in upcoming handbook changes.

   KEY POINT: The UER was designed to supplement proven standard egress procedures NOT to interfere with or replace egress standards.

   Basic Egress - Water
   - Reference Point - Locate
   - Emergency Exits Within Reach - Locate and Jettison
   - Mike Cord - Disconnect
   - ** If time permits, inflate re-breather vest and insert mouthpiece before immersion.

   ** **Warning****
   In all likelihood, personnel who were unsuccessful in the operational use of the UER in training will be unsuccessful in an attempt to use the UER re-breather during an actual underwater egress.

- Take a normal breath before submerging and wait until completely immersed (recommend 5 - 8 seconds).

- Seatbelt / Harness - Release and clear from vest while holding reference point.

- If hung up in seat, entangled in debris or exit is blocked; activate re-breather vest, insert mouthpiece and utilize re-breather as necessary while continuing egress.

- Egress - Holding reference points, exit at right angles to the aircraft.

   ** **Warning****
   Failure to maintain a handhold on a Reference Point until clear of the aircraft could result in disorientation.

   Anti-exposure coveralls, wet suits, and inflated life vests all exhibit positive buoyancy which may inhibit egress, but may be overcome by use of standard hand-over-hand egress techniques.

- Life Vest - Inflate when clear of aircraft (CO_2).

** **Warning****
If fuel or oil covers the water surface, do not ignite signal device.

9. *Additional Information about the Vest and Training*

   a. The UER vest utilizes oxygen instead of air to allow for a longer period of re-breathing.

   b. Nose clips were not provided with the vest to reduce the complexity of operation . . . one less item to lose or fail on a dark and stormy night.[i] Nose clips are not allowed for training because they do not help you to develop vital techniques, which may save your life in an accident.

   c. The UER in the 9D-5. The UER vests were repeatedly tested and proven to work for egress in the dunker under very controlled conditions. The vests are not allowed by the Navy in the 9D-5 under normal training conditions because of the large number of students being trained coupled with the potential for injury associated with buoyant ascent after breathing pressurized gas. The Shallow Water Egress Trainer (SWET) device can provide the UER training you need to survive without the risk.

   d. Why not replace the 9D-5 Underwater Egress Trainer with the SWET device for Coast Guard egress training? There is some training gain in the use of the SWET device in addition to the 9D-5. It does not sufficiently ingrain the total package of egress procedures as well as the 9D-5. Analysis of recent accident information has revealed that we cannot afford to reduce the egress training provided by the 9D-5. Recency and repetition have significant impact on training retention. You don't have to like the 9D-5 training to recognize that it is good for you.

Key Points to Remember

1. The Underwater Escape Re-breather Vest was designed to assist with and not replace proven egress procedures.

2. The Underwater Escape Re-breather Vest is not a scuba or salvage device. Do not attempt to re-enter the aircraft once you have successfully egressed.

3. The Underwater Escape Re-breather Vest does not "run out of air." Through re-breathing, the gas inside gets progressively worse until it will not support life. You have approximately two minutes of good quality re-breathing time on the device.

4. If you were not successful in the operational use of the UER vest in training, you are even less likely to succeed using it with the added stress of an accident. Stick with the standard egress procedures without the re-breather.

[i]This use or non-use of nose clips is an individual choice. Some people simply can't use either an EBS or a re-breather without a nose clip. We do not deny the students a nose clip if it is the only way that they can use the system.

Underwater Escape Re-breather Vest Training - Pool Phase

Experience has proven that maximum reasonable scheduling for the pool phase is 12 persons per four hour (½ day) session. The trainees may be divided into two six-person groups.

1. The support equipment required in this phase includes the following:
- Snorkel (3)
- Divers Mask (2)
- LPU-25 Vests (6)
- Oxygen cylinders
- Shallow Water Escape Trainer (SWET) device

2. Clothing to be worn by trainees:
- Cranial protection (helmet)
- Flight gloves
- Flight suit (optional)
- Swim suit
- Sneakers or wetsuit booties
- Shorty wetsuit (optional)

3. Snorkel Phase

   a. Using the snorkel, breathe above the water through the mouth with the nose closed off.

   b. Using the snorkel, breathe with face underwater for one minute without holding the nose. Prior to completion of this step, have trainee open eyes underwater and continue breathing.

   Note: This is done due to sinus pressure differences with eyes open and closed. One technique is to have the instructor hold fingers in front of trainee and have trainee repeat number shown.

   c. With trainee using thumb or hand to block end of snorkel for exhalations only, have the trainee inhale through the snorkel and exhale around the mouthpiece for 10 breathing cycles. This is to enable trainee to practice venting techniques required if unable to exhale into full oxygen bladder when initially activated.

4. Re-breather Valve Phase.

   This phase may be done with a UER vest, which has been inflated orally by the trainee.

   a. Review the requirement to <u>always</u> exhale en route to the surface to avoid <u>EMBOLISM</u> and <u>always</u> close mouthpiece valve before removing from mouth to prevent deflation of vest.

   b. Clearing of mouthpiece:

      i. Insert mouthpiece into mouth underwater, surface, and clear mouth by forcing water out <u>before</u> opening valve.

ii. Open mouthpiece valve and take first breath cautiously. There may be a slight amount of water remaining, which may be swallowed or carefully breathed around. Caution: Rapid inhalation may cause water to be ingested into lungs, which can lead to choking and other complications. Continue breathing until comfortable (one minute maximum). Close mouthpiece before removing from mouth.

iii. Repeat steps i and ii remaining underwater for entire cycle until breathing comfortably underwater (one minute maximum). Surface and close mouthpiece before removing from mouth.

5. SWET Device Phase.

The SWET device must be placed in water depth, which allows for the seat to be totally above the surface when upright.

a. Instructor roles

b. Handle operator - supervise operation.

i. Briefs trainee and safety personnel stressing reference points
ii. Verifies proper routing and security of seat harness
iii. Verifies oxygen toggle is clear
iv. Controls immersion / extraction of trainee

c. Safety person - uses diver's mask and snorkel. Remains inside SWET device during training immersion.

i. Evaluates egress procedures (observes underwater during entire immersion of trainee).

ii. If trainee safety is compromised, signal to handle operator for extraction and lift trainee to bring head above surface.

iii. Debrief trainees at completion of cycle.

iv. Major debrief points
- Maintain reference points
- Clearing harness
- Control panic / don't rush
- Exhale during ascent
- Close mouthpiece before removing from mouth

v. Other Debrief Points.

Desirable but not critical:
- Head and shoulders back in seat (don't assume fetal position)
- Exit from desired side of device

- Ride 1 - *Basic Egress with UER Worn, But Not Inflated*
  - Brace for impact
  - Invert slowly
  - Normal egress procedures without UER inflation
  - Safety person debrief

- Ride 2 - Egress with UER Worn and Inflated Prior to Immersion
  - Brace for impact.
  - Inflate UER, insert mouthpiece, open valve, start breathing. Trainee signal when ready to invert.
  - Invert slowly.
  - After 30 seconds of breathing inverted, and when safety person signals OK, commence normal egress with extra attention to clearing harness and maintaining reference points.
  - Exhale during ascent to surface.
  - Close mouthpiece prior to removing from mouth.
  - Locate and operate $C0_2$ inflation toggle (dummy bottle).
  - Safety person debrief.

- Ride 3 - *Egress with Blocked Exit* UER Worn and NOT Inflated Until Reaching Blocked Exit.
  - Brace for impact.
  - Invert slowly. Perform normal egress.
  - Upon reaching edge of SWET device underwater, and while holding reference point, inflate UER, insert mouthpiece, and breathe normally until signaled to surface.
  - Exhale during ascent to surface.
  - Close mouthpiece prior to removing from mouth.
  - Locate and operate CO_2 inflation toggle (dummy bottle).
  - Safety person debrief.

- Ride 4 - *Egress When Trapped in Seat* UER Worn and Not Initially Inflated.
  - Brace for impact.
  - Invert slowly.
  - After inverted, inflate UER, insert mouthpiece, and breathe normally.
  - After 30 seconds of breathing inverted, and when safety person signals OK, commence normal egress with extra attention to clearing harness and maintaining reference point.
  - Exhale during ascent to surface.
  - Close mouthpiece prior to removing from mouth.
  - Locate and operate CO_2 inflation toggle (dummy bottle).
  - Safety person debrief.

* Caution: Maximum time re-breathing on UER during any single inflation should be two minutes.

6. Log students after completion of training for completion of minimum training and note if successful or unsuccessful in the functional use of the vest.

7. Participation in the training is mandatory. There is no pass / fail criteria for UER training, which will result in grounding.

8. The UER is to be worn by trained aircrew members only. It is not to be worn by untrained personnel. The minimum training for over water aerial flight in Coast Guard aircraft, wearing the LPU-25/P, is current completed training in the 9D-5 egress trainer and the LPU-25/P training as described in this lesson plan.

The Development of a Course Training Standard and Protocol for Instructors
It is also essential to have a course training standard with performance objectives in place before the training starts. The one developed by Survival Systems Limited, Dartmouth, Nova Scotia, is published here for operators to use as a template.

5.1.2 SURVIVAL SYSTEMS LTD. TRAINING STANDARD

Combined Aircraft Ditching and Emergency Breathing Course

TRAINEE: ______________________ DATE: ______________________

COURSE: __________ INSTRUCTOR: ____________ SEAT: PILOT POSITION

DAY 1

NOTE: Those tasks marked with an asterisk (*) are Performance Checks.

EBS EXERCISES	**PASS**	**FAIL**
1. General equipment and underwater breathing familiarization	______	______
2. Breathe scuba underwater	______	______
3. Demonstrate scuba purging procedures	______	______
4. Breathe EBS underwater	______	______
5. Demonstrate EBS purging procedures	______	______
6. Demonstrate breathing pattern using EBS 1 to 1 ½ minutes underwater	______	______

SWET EXERCISES		
1. Board Shallow Water Egress Training (SWET). Brief. Invert SWET. Trainee counts to four. Trainee gives emergency signal (places both hands on top of helmet). Instructor rights SWET.	______	______
2. Invert SWET, EBS procedures. Egress SWET	______	______
3. Invert SWET. EBS procedures. Jettison exit. Egress SWET	______	______
4. Invert SWET. Operate exit. Simulated jammed EBS procedures. Jettison exit. Egress SWET.	______	______
5. Invert SWET. Jettison exit. Exit simulated jammed. EBS procedures. Secondary exit procedures. Operate and jettison exit. Egress SWET.	______	______

MODULAR EGRESS TRAINING SIMULATOR (METS™) / AIRCRAFT DITCHING COURSE (ADC) EXERCISES

	PASS	FAIL
1. Pilot's position (surface). Hands on controls. Jettision and clear exit. Assume modified brace position. (Invert). Release harness. Egress	________	________
2. *Pilot's position. Hands on controls. (Invert). Jettison and clear exit. Locate exit frame. Release harness. Egress.	________	________
3. *Pilot's position (semi-darkness). Hands on controls (Invert). Jettison and clear exit. Locate exit frame. Release harness. Egress.	________	________
4. Pilot's position. Hands on controls. (Invert) Jettison exit. Exit jammed. Cross-cockpit procedure. Locate co-pilot's seat back. Release harness. Egress.	________	________

METS™ COMBINED EXERCISES

	PASS	FAIL
1. Pilot's position. Hands on controls. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
2. *Co-pilot's position. Assume brace position. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
3. *Pilot's position (night conditions). Hands on controls. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
4. Pilot's position. Hands on controls. (Invert). Jettison exit. Exit jammed. EBS procedures. Cross-cockpit procedure. Locate co-pilot's seat back. Release harness. Cross-cockpit. Exit open. Locate exit frame. Egress.	________	________

DAY 2

SURFACE ABANDONMENT POOL SESSION

1. Scramble Net Ascent ______
2. Jump from Height/Inflate Lifejacket ______
3. Chain/Huddle/Raft Formation ______
4. Surface Abandonment - 2 Sequences ______
   (Hover and Surface Evacuation)
5. Liferaft Inflation, Righting and Boarding ______
6. Survival Pattern ______
7. Rescue Procedures ______

SWET EXERCISES (IF REQUIRED)	PASS	FAIL
1. Invert, activate EBS, egress	________	________
2. Invert, jammed exit, activate EBS, egress	________	________
3. Invert, simulated jammed exit, activate EBS egress cross-cabin (exit in)	________	________

METS™ / ADC EXERCISES

1. Pilot's position hands on controls (Invert) Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress .	________	________
2. *Co-pilot's position. Assume brace position. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress .	________	________

METS™ ADVANCED EXERCISES 90° - 180° ROLLS

1. Pilot's position. Hands on controls. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
2. *Co-pilot's position. Assume brace position. (Invert). Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
3. *Pilot's position (night conditions). Hands on controls. (Invert).Jettison and clear exit. EBS procedures. Locate exit frame. Release harness. Egress.	________	________
4. Pilot's position. Hands on controls. (Invert). Jettison exit. Exit jammed. EBS procedures. Cross-cockpit procedure. Locate co-pilot's seat back. Release harness. Cross-cockpit. Exit closed. Jettison and clear exit. Locate exit frame. Egress.	________	________
5. Pilot's position. Hands on controls. (Invert). Jettison and clear exit. Exit jammed. Locate reference point. Release harness. Egress through rear cabin.	________	________

PERFORMANCE CHECK	PASS	FAIL
a) normal crew position	______	______
b) in simulated night conditions	______	______
c) without assistance	______	______
d) inverted	______	______
e) operate emergency exit	______	______
f) wearing immersion suit, helmet, lifejacket, belts, backpack if applicable	______	______
g) alternate crew position in daylight conditions	______	______
h) utilize Emergency Breathing System	______	______
i) cross cockpit escape	______	______

NOTE: A failed exercise occurs when the instructor or safety diver is required to render assistance to the trainee to complete the performance check or the trainee's performance did not meet the standard required by the Course Training Standard (CTS).

UNDERWATER ESCAPE TRAINING ASSESSMENT **/ A / B / C / U /**

INSTRUCTOR COMMENTS: Following the underwater escape-training phase, the trainee's overall performance shall be assessed by the instructor and rated by the use of one of the following terms:

A **Superior:** The trainee performed all tasks consistently better than required by the CTS.

B **Good:** The trainee experienced no difficulty performing the tasks to the standard required by the CTS.

C **Average:** The trainee experienced some difficulty, but performed all tasks to the standard required.

U **Unsatisfactory:** The trainee's overall performance did not meet the standard required by the CTS. Two (2) or more unsuccessful egress sequences constitute failure and no certificate will be issued.

NOTE: Should the trainee's performance be judged unsatisfactory, the instructor will write an assessment report with the recommendations. This information will be passed to the appropriate Group HQ and subsequently to the trainee's CO. The decision on appropriate follow-up action will rest with the CO.

COMMENTS:

5.1.3 ONGOING TRAINING

Even after the EBS has been introduced, it is important to continue with refresher training, both at the monthly squadron briefings and in the Flight Safety literature. The following example from the US Army Safety Centre, May 1992 Flight Fax provides a very good example of how to reinforce the training.

"While you're submerged in water and darkness and disoriented as your helicopter is sinking is not the time to discover your HEED doesn't work properly. It's part of your survival equipment - but it can't help you survive if it doesn't work.

To ensure that it works correctly all the time, NAVAIR 13-1-6.5 lists preflight and post-flight inspections that the Navy air crewmembers must perform on their HEED before and after each flight. If your unit has HEEDs and doesn't already have a required set of inspection procedures, the following pre-flight and post-flight procedures adapted from NAVAIR 13-1-6.5 could be helpful.

Pre-Flight Inspections

- *Visually inspect the device for external damage.*

- *Inspect the mouthpiece assembly for security and cleanliness.*

- *Turn the ON / OFF valve to the ON position and check the device for operational charge. The indicator pin should be flush with or above the green notch.*

- *Manually purge the regulator by momentarily depressing the purge button. Air should be released from the regulator (indicated by a continuous audible hiss from the mouthpiece assembly).*

- *Ensure the HEED is properly secured to the SV-2 survival vest.*

Note: The HEED should remain in the ON position during the flight. The indicator pin must be flush with or above the green notch for flight.

- *Return the HEED for replacement or repair if discrepancies are noted.*

Post-Flight Inspection

- *Check the pressure indicator to ensure the pin is above the green notch.*

- *Turn the ON / OFF valve to the OFF position.*

- Depress the purge button until the airflow stops.

- Inspect the device for external damage.

- Inspect the mouthpiece for cleanliness and security.

- Inspect the regulator for signs of salt air, water contamination, and cleanliness.

- Return the HEED for replacement or repair if discrepancies are noted.

Remember that any missing part following flight can be a FOD hazard. Even a small part from your HEED could lead to disastrous results if it's adrift and finds its way into critical aircraft components or flight controls. Neglecting your pre-flight and post-flight inspections could lead to this lifesaving device failing you at a most critical time or to its becoming a potential FOD hazard."

As a further follow on to the introducing a new piece of equipment into service, it is essential to provide feedback to the operator as to how it has performed.

Why do some helicopter crewmembers choose not to use their HEED bottle?

Proper training in the use of the HEED is essential for safe operation. However, once crewmembers are properly trained, they are sometimes still reluctant to use the HEED during ditchings. The facts and thought-provoking issues addressed in the following article (By Lt Cdr DJ Thorn, taken from the December 1991 Issue of "Approach") should alleviate some of the fears associated with using the HEED.

"It was to have been a routine surface search and contact mission in the Persian Gulf. As the SH-60B lifted from the frigate and the pilot applied power to transition to forward flight, a blade in the first stage of the gas generator vibrated loose. The crew heard a loud bang as the engine destroyed itself. Ten seconds later, the helicopter hit the water, rolled over on its right side, and sank.

The pilot took a breath and escaped through his emergency window. The sensor operator waited until all motion ceased. As water filled the cabin, he put his HEED bottle in his mouth and drew a breath of air. When the pressure equalized, he opened his emergency window and got out.

The copilot took a good breath before going under, but he couldn't open his emergency window. He got his door partially open and was on his way out when it slammed shut, pinning his helmet and right hand. He inhaled a little water and started to panic. Then he saw light coming through the pilot's window. He braced his feet on the centre console and pushed against the door, freeing his right hand. After unstrapping his helmet, he shot through the pilot's window. Finally, clear of the aircraft, he was disoriented but remembered to blow out some air to figure out which way was up. The pilot and sensor operator saw him clawing his way to the surface in what could have been the last seconds of his life.

All three of these crewmen were trained in the use of HEED, yet only one chose to use it. You could say that since all three survived, they all made the right decisions. You can't argue with success. However, the copilot was within seconds of drowning.

In another HEED related incident, an SH-2F on a surveillance mission entered a descending, decelerating turn to identify an object in the water when the aircraft began to yaw uncontrollably to the right. It spun four or five times before it hit the water and sank. The cabin filled with water, and the helicopter rolled over on its right side. Although the first crewman was not able to take a breath of air before going under, he had no trouble getting out. The second crewman was able to take breath, but became disoriented as the aircraft rolled over. He pulled his HEED bottle out, took a breath, and then released his lap belt. As he was getting out, he dropped his HEED bottle, but since it was tied to his SV2, he recovered it. Although the mouthpiece was full of water, he purged it and got another breath of air. He said later that the HEED saved his life. The helicopter aircraft commander first tried to get out through the cargo door, but it was jammed. The he looked for his HEED bottle but could not find it (it was not properly tied to his SV-2).

He noticed the copilot's door was blocked, so he crawled to the aft cabin, getting stuck in the process. Just before passing out, he managed to clear the aircraft, although he can't remember how. The two crewmen revived him on the surface. Searchers were only able to find the copilot's helmet and seat cushion. The investigator's believe he lost his helmet, hit his head, and drowned.

It is unlikely that in this case that the HEED could have saved the copilot. Evidence suggests that he was incapacitated on impact. Since his seat cushion floated to the surface, he may have released his lap belt (or it may have failed). The second crewman was about 30 feet under water when he finally escaped. Why do some helicopter crewmembers choose not to use their HEED bottle? Part of the answer is in training; another part is in attitude. As with automatic actuating devices in survival equipment, such as the FLU-8P for TACAIR crews, using the HEED bottle is not the primary method of escape. The first option is to quickly get out of the aircraft. If the crewmembers encounter any delay or difficulty, then they use their HEED bottle. When do you consider yourself delayed? How long will you try to escape before pulling out your HEED bottle? If you wait too long, you may not have the presence of mind to remember to purge the regulator, if you even remember you have a HEED bottle at all. The HEED bottle lasts at least two minutes at 20 feet and 50°F. During tests, it averages 3.1 minutes.

When HEED training was just getting started, two incidents occurred that were treated as arterial gas embolisms - but were probably hyperventilation. Neither aviator suffered long-term injury or disability. Yet, stories that arose from these incidents, and the fears of helicopter crews today about embolism, may be an underlying factor in deciding whether to use the HEED or not.

SINCE MAY 1987, 26 AVIATORS HAVE USED THE HEED DURING EGRESS. NOT ONE EXPERIENCED EMBOLISM. CONVERSELY, IN THE SAME MISHAPS, EIGHT PEOPLE DROWNED, SEVEN OF WHOM COULD HAVE USED THE HEED. WHY DIDN'T THEY? WHAT'S YOUR GAME PLAN? ARE YOU WORRIED THAT YOUR HEED WILL GIVE YOU AN EMBOLISM? YOU CAN BE TREATED FOR EMBOLISM; DROWNING IS PERMANENT!"

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CHAPTER 6

Conclusions and Recommendations

The data obtained from over thirty years of military and civilian helicopter ditchings is presented in this AGARDograph. The helicopter, being unstable in the water, rapidly sinks upright or floats inverted in about 50% of cases. There is often less than 15 seconds warning prior to the accident and the fatality rate in survivable accidents has stubbornly remained consistently at about 15 and 50 percent. It can be even higher in a single helicopter accident that occurs at night.

The crew and passengers are stunned on impact, find themselves inverted underwater, forced back into their seats by in-rushing water and disoriented. The sudden explosion from the hot exhaust pipes suddenly cooled in the water can also cause alarm. In this situation, they have to re-orient themselves, release their harness and make their way to an emergency exit, the pathway may not resemble that of the pre-accident condition. In the process, they may be hampered by darkness, debris, bubbles, and panicking or dead colleagues. Finally, on locating an exit, they must find and operate the mechanism for jettisoning the door, window, or hatch before making their escape. These are not easy actions to perform; engineers have not tended to take into account the fact that only very simple things can be accomplished under such conditions - escape pathways have usually been designed for emergency ground egress, not emergency egress underwater.

During this whole event, the crew and passengers must breath-hold. The ability to do this is seriously impaired in cold water and, for many individuals, breath-hold time may not be sufficient to provide the 27-92 seconds required to make an underwater egress. Water temperature in the North Atlantic and North Sea is less than 15°C for most of the year. It is therefore probable that those who have failed to escape from the helicopter during a survivable ditching have drowned through simply not being able to breath-hold for long enough. It follows that those at most risk are in the most remote parts of the helicopter, aisle seats or in the aft section for example. Herein lies the rationale for the provision of some form of emergency breathing aid.

It has taken military and civilian authorities fifteen years to appreciate these facts and take action. Drowning in a helicopter ditching has tended to be accepted as an occupational hazard, in much the same way as it is in the marine world. As a consequence, in both scenarios drowning following entrapment tends to evoke less concern than hypothermia at the surface of the sea.

Of the two theoretical options available i. Enabling people to stay underwater longer (i.e. provide an emergency breathing aid) or ii. Getting them out more quickly and efficiently, the second was pursued initially and underwater escape training for helicopter crew and professional passengers was provided. The authorities did not consider it cost effective to train passengers in the techniques of underwater escape. As the offshore oil industry increased, the majority of oil companies in conjunction with local legislation, insisted that all employees must undertake some form of training. If this was not possible, a trained rescue specialist had to accompany them on board the helicopter. The training was copied from the original US Navy Dilbert Dunker concept for fixed wing aircrew training. The US Navy 9D-5 trainer was developed specifically for helicopters. At least 10 units were built by Burtech Inc., and established in Navy air stations across the United Sates. In the UK the Royal Navy trained fixed wing aircrew in underwater

breathing at the Royal Navy Air Medical School at Lee-on-Solent, Hampshire and helicopter aircrew in underwater escape in a dunker at HMS Vernon Portsmouth. Subsequently, the Robert Gordon Institute of Technology, in Aberdeen started training civilian offshore workers with a dunker manufactured by McLean & Gibson, and the RN moved their dunker training to RNAS Yeovilton. Canada originally used a Royal Canadian Navy Dilbert Dunker, followed by a McLean & Gibson machine, at Survival Systems Limited. Survival Systems Limited then developed their own series of Modular Egress Training Simulators (METS™), these are now used in various locations around the world. All these simulators have certainly helped survivors to escape; there are many testimonies to this.

Despite this training, the fatality rate in survivable accidents continued to remain at about 15%, and the provision of some form of EBS had to be considered. The Royal Navy took an old United States Navy concept from World War II and developed a Helicopter Escape Breathing Apparatus. Unfortunately, this idea did not come to fruition. It is to the credit of the United States Coast Guard that they were the first to introduce a purpose built LPU-25P lifejacket and underwater breathing apparatus using 100% oxygen into their helicopter fleet following three serious accidents in the late 1970s. This was followed by the introduction of the HEED 2 by the USN, a modified HEED 2 with the bottle in the slimline backpack by the Canadian Navy, and the STASS by the Royal Navy and Royal Air Force. After 10 years of use, both the USN and Canadian Navy have now introduced second generation devices into service. For the civilian, UK offshore oil industry, the development and provision of EBS for helicopter passengers and crew was pioneered by The Robens Institute, The Shark Group and Shell UK, and their introduction for passengers preceded the provision for passengers in military aircraft.

There remains an ongoing debate about the relative merits of re-breather compared to compressed air/oxygen EBS. No single answer can be provided; the ideal solution will depend on variables, that will be specific to each operating scenario, and will vary with factors such as: water temperature; other protective clothing worn; budget; training available; medical facilities available and so on. What can be stated is that hybrid EBS devices that combine a re-breather and source of compressed air should be regarded in the same way as a compressed air EBS.

The HEED has saved lives, but there have been some problems with it. These have been due to the fact that the unit was an add-on to some other part of the life support equipment, or that crew failed to complete the necessary pre-flight checks correctly. Generally the training packages have worked well. It is concluded that irrespective of whether a compressed air / oxygen system or a simple re-breather is used, it is essential that it forms part of an integrated survival system and that the crew and passengers are trained in its use and in water as well as air. The progression should be: **AIR** to **Shallow Water Escape Trainer** to **HUET**.

Several issues remain to be resolved:

- In many countries the decision to issue EBS and to provide training to all professional passengers is yet to be made.
- The true value of “dry” training in EBS is yet to be established.
- There is a need for agreed specifications and testing procedures for helicopter EBS.
- Helicopter manufacturers should consider designing and building underwater breathing system into helicopters designated for Maritime operations. To date, there are no military or civilian long-term research and development programs to do this. The only efforts are still aimed at adding something onto pre-existing equipment.

To conclude on an encouraging note, twenty years ago there were no commercially available helicopter EBS on the market to assist crew and passengers. Today, as we have seen, the dangers have been identified, the possible solutions proposed, and a variety of companies are offering compressed air, re-breathing or hybrid EBS for sale. We look to the 21st century with the hope that the outstanding issues will soon be resolved, and that the next generation of EBS will be purpose built and integrated into the helicopter and/or personal survival equipment.

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We both hope that the huge amount of work put into this AGARDograph will be of benefit to regulators, operators, and helicopter crew and passengers alike. If it saves one life then it will have been worth the effort.

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References

1. Air Sea Rescue Bulletin. NAVCG 128. Oxygen Equipment Aids Escape From Submerged Aircraft. Vol. II, No 1. United States Navy Museum, Washington, D.C. September 1945.

2. Allen, J.R., Brennan, D.H., Richardson, G. Detectability of Emergency Lights for Underwater Escape from Rotorcraft. Aviat. Space Environ. Med. 1989; 60: 199-204.

3. Anton, D. J. (1984) A Review of UK Registered Helicopter Ditchings in the North Sea. Int. J. of Aviat. Safety 2:55-63.

4. Baker, K., Harrington T. (1988) An Analysis of RN Rotary-wing Aircraft Ditchings from Jan 1974-Dec 1982. RN, INM Report 3/88.

5. Balmi, P. J., Tipton, M. J. (1991) Investigation of the Minimum Possible Volume for a Simple Emergency Breathing System. Robens Institute Report, University of Surrey.

6. Barker, C.O., Yacavone, D.W., Borowsky, M.S., Williamson, D.W. Helicopter Crash Survival at Sea - United States Navy / Marine Corps Experience 1977 - 1990. AGARD Conference Proceedings. Turkey. May 1992.

7. Barker, C.O., Bellenkes, A.H. US Naval Helicopter Mishaps: Cockpit Egress Problems. Aviat. Space Environ. Med. 1996; 67: 63-64.

8. Benham, J.A., Redman, P.J., Haywood, P. An Interim Report on the Development of Safe Underwater Escape from Helicopters. DRA / CHS / PHYS / WP95 / 017. Defence Research Agency Foundation. June 1995.

9. Benton P.J., Woodfine J.D., Westwood P.R. Arterial Gas Embolism Following a 1 – Meter Ascent During Helicopter Escape Training: A Case Report Aviat. Space Environ Med. 1996; 67: 63-64.

10. Bohemier, A., Chandler, P., Gill, S. Factors Effecting Egress from a Downed, Flooded Helicopter. COGLA Tech. Report 109. 355 River Road, Ottawa. February 1991.

11. Broadsmith, M. Westlands Aerospace Personnel Communication. November 1989.

12. Brooks, C.J. Canadian Aircrew Sea Water Survival. 1952-1987. DCIEM Report No. 88-RR-39. September 1988.

13. Brooks, C.J. Canadian Aircrew Fresh Water Survival. 1952-1987. DCIEM Report No. 88-RR-S1. December 1988.

14. Brooks, C.J. The Human Factors Relating to Escape & Survival from Helicopters Ditching in Water. AGARDograph No. 305E. Neuilly sur Seine ISBN 92-835-0522-0. 1989.

15. Brooks, C.J., Bohemier, A.P., Snelling, G.R. The Ergonomics of Jettisoning Escape Hatches in a Ditched Helicopter. Aviat. Space Environ. Med. 1994; 65: 387-95.

16. Brooks, C.J. Designed for Life - Life Jackets Through the Ages. Mustang Survival Canada. ISBN 0-69913-0-4. August 1995.

17. Brooks, C.J. Surviving a Helicopter Ditching: An Engineering Challenge. A21-1-A21-8. AGARD-CP-600. Vol. 1. Palaiseau, France. April 1997.

18. Brooks, C.J., Bohemier, A.P. Helicopter Door and Window Jettison Mechanisms for Underwater Escape: Ergonomic Confusion. Aviat. Space Environ. Med. 1997; 68: 844-57.

19. Brooks, C.J., Muir, H.C., Gibbs, P.N.A. An Initial Investigation of Passenger Evacuation from the Super Puma Helicopter. Report to Natural Resources (Canada). Ottawa. 31 March 1999.

20. Brooks, C.J. The Abysmal Performance of the Inflatable Liferaft in Helicopter Ditchings. RTO Conference Proceedings San Diego. ISBN 92-837-1016-9. June 1999.

21. Brooks C.J., Cheung S.S., d'Eon N.J. Breath-holding Ability of Students Attending the Basic Helicopter Survival Training Course (BST). Report to Natural Resources. (Canada) April 2000.

22. Chen, C.T.C., Miller, M., Fogarty, K.M. Rotorcraft Ditchings and Water Related Impacts That Occurred from 1982-1989. Phase I Report. DOT/ FAN/CT-92/12/. October 1993.

23. Civil Aviation Authority. A Review of Helicopter Airworthiness. London, UK. 1984.

24. Civil Aviation Authority. Review of Helicopter Offshore Safety and Survival. CAP 641. ISBN 0-86039-608-8. London, UK. 1995.

25. Clifford W.S. Helicopter Crashworthiness, A Review of U.K. Military and World Civil Helicopter Water Impacts from 1971 – 1992. CAA Report 96005, July 1996.

26. Cunningham, W.F. Helicopter Underwater Escape Trainer (9D-5). AGARD Conference Proceedings. No 255. ISBN 92-835-0226-4. December 1978.

27. Davidson, A.F., Wagner, P.R. Assessment of the Underwater Performance of the Normalair Seat Mounted Oxygen Regulator with Remote Pressure Sensing Modification. R.A.F. Institute of Aviation Medicine. Tech Memo 259. October 1965.

28. Davidson A.F., The Principles of Underwater Escape from Aircraft. AGARDograph No 230. Neuilly sur Seine. ISBN 92-835-1262-6. November 1977.

29. Eberwein, J. The Last Gasp. United States Naval Proceedings. July 1985.

30. Frew, J.A. Helicopter Emergency Breathing System Evaluation. DCIEM Tech Memo HPSD 93-15. Toronto, Ontario, Canada. November 1993.

31. Gierbolini, L.A., Wensel, J. Helicopter Aircrew Underwater Breathing Device. SRU-40/P. NAWCAD Patuxent River MD.

32. Giry, P., Courcoux, P., Taillemite, J.P. Accident D'Hélicoptère au Dessus de L'eau dans La Marine Nationale. 1980-1991. Neuilly Sur Seine. NATO AGARD Conference Proceedings. No 532 ISBN 92-835-0687-1. 1992.

33. Gray, C.G. et al. United States Coast Guard Emergency Underwater Re-breather Evaluation; USNEDU. Panama City, Florida. April 1981.

34. Hayes, P.A. The Development and Performance of Underwater Escape Devices. Report to SCICAD Ltd. MSC 642060/0S5.

35. Haywood, J.S., Hay, C., Mathews, B.R., Overwheel, C.H., Radford, D.D. Temperature Effect on the Human Dive Response in Relation to Cold Water Near Drowning. J. Appl. Physio: Respirat. Environ. Exercise Physiol. 56.(1) 202-206. 1984.

36. Hayward, J.S., Eckerson, J.D. Physiological Response and Survival Time Predictions of Humans in Ice Water. Aviat. Space Environ. Med. 1984; 55: 206-212.

37. Hynes, A.G. Emergency Underwater Escape System. DCIEM Tech Memo 3614H12-10 (MLSD). Toronto, Ontario, Canada. April 1982.

38. Hynes, A.G. Emergency Breathing System – Aircraft Underwater Egress. DCIEM Tech Memo 3614H12-10 (MLSD). Toronto, Ontario, Canada. November 1983.

39. Keatinge, W. R. & Nadel, J. A. (1965) Immediate Respiratory Response to Sudden Cooling of the Skin. J. Appl. Physiol., 20:65-9.

40. Kinker, L.E., Loeslein, G.F., Contarino, R. US Naval and Marine Corps Helicopter Trends: Over Water Mishaps (1985-1997). RTO Conference Proceedings, San Diego. ISBN 92-837-1016-9. June 1999.

41. Kinker, L.E., Loeslein, G.F., O'Rourke, C.A. Naval and Marine Corps Rotary Wing Over Water Mishaps and the Life Raft Improvement Program. RTO Conference Proceedings, San Diego. ISBN 92-837-1016-9. June 1999.

42. Maddern, T. A., Hayes, P. A., Tipton, M. J. (1991) Hydrostatic and Resistive Performance of Counterlungs Shark Group Report.

43. Malejczuk, D.S. EBS Replacement Phase II Evaluation. DCIEM Tech Memo HPSD-94-06. Toronto, Ontario, Canada. April 1994.

44. Marwinski, H.D. Helicopter Flight Accidents in the German Federal Armed Forces in the Last 15 Years (1984 – 1997). R.T.O. Conference Proceedings San Diego. ISBN 92-837-1016-9. June 1999.

45. McKinley, M. HEED 2. All Hands. February 1988.

46. National Hyperbaric Centre (1989a) Tests of Re-breathing Equipment – Dry Trials. NHC Report.

47. National Hyperbaric Centre (1989b) Tests of Re-breathing Equipment – Phase 1. NHC Report.

48. National Hyperbaric Centre (1989c) Tests of Re-breathing Equipment – Final report. NHC Report.

49. Reader, D.C. Helicopter Ditchings, British Military Experience. 1972 - 88. RAF Institute of Aviation Medicine. Report No. 677. March 1990.

50. Report 27th Meeting of Air Standardization Coordination Committee, WP61. USN Project Group 61 / 102 Annex C, Appendix 111. 1986.

51. Rice, E.V., Grear, J.F. Underwater Escape From Helicopters. SAFE 11th Annual Symposium. 1973.

52. Royal Naval Survival Equipment School Helicopter Emergency Breathing Equipment Trial Report to Flag Officer Naval Air Command. 20 June 1975.

53. Roythorne, C. (1981) Cold in North Sea Operations. In: J. M. Adams (ed). Hypothermia Ashore & Afloat. Proceedings of the 3rd International Action for Disaster Conference, Aberdeen University Press, Aberdeen.

54. Russell, K.L. Helicopter Emergency Egress Device (HEED) Evaluation of Current and Non-Developmental Item (NDI) Sample. NEDU Technical Report No. 11-95. Panama City, USA. May 1995.

55. SCICAD (1990) Tests of Re-breathing Equipment Phase II. Helicopter Underwater Escape Apparatus. SCICAD Ltd. Report.

56. Steele-Perkins, A.P., Johnston, R.P., Barton, P. Royal Naval Helicopter Ditching Experience. AGARD Conference Proceedings No 532. Turkey. ISBN 92-835-0687-1. May 1992.

57. Sterba, J. A., Lundgren C. E. G. (1979) Influence of Water Temperature on Breath-Hold time in Submerged Man. Undersea Biomedical Research 6(Suppl.): 29-30.

58. Sturgeon, W.R. Development of an Emergency Underwater Escape Breathing System for CH124 Sea King Aircrew. DCIEM Technical Report. No 88-TR-11. April 1988.

59. Theriault, P.G. Helicopter Emergency Breathing System (EBS) Evaluation. DCIEM Technical Note 12A / 2 / 3.1 (PSO). 1998.

60. Tipton, M. J. (1989) The Initial Responses to Cold-Water Immersion in Man. Editorial Review, Clinical Science 77: 581-588.

61. Tipton, M. J., Vincent, M. J. (1989) Protection Provided Against the Initial Responses to Cold Immersion by a Partial Coverage Wet Suit. Aviat. Space Environ. Med. 1989. 60(8): 769-773.

62. Tipton, M. J., Stubbs, D. A., Elliott, D. H. (1991) Human Initial Responses to Immersion in Cold Water at 3 Temperatures and Following Hyperventilation. Journal of Applied Physiology 70(1): 317-322.

63. Tipton, M. J., Balmi, P. J. (1992) "Air Pocket" Phase IV Trials: Concept Evaluation. Robens Institute Report, University of Surrey.

64. Tipton, M. J. (1992a) Air Pocket Phase V & VI: Evaluation in Cold Water. Robens Institute Report, University of Surrey.

65. Tipton, M. J. (1992b) Air Pocket Phase VII: Evaluation During Simulated Helicopter Underwater Escape. Robens Institute Report, University of Surrey.

66. Tipton, M. J. (1993) The Concept of an “Integrated Survival System” for Protection Against the Responses Associated with Immersion in Cold Water. Journal of the Royal Naval Medical Service 79: 11-14.

67. Tipton, M. J., Kelleher, P., Golden, F. St.C. (1994) Supraventricular Arrhythmias Following Breath-hold Submersions in Cold Water. Undersea & Hyperbaric Medicine 21(3): 305-313.

68. Tipton, M. J., Balmi, P. J., Bramham, E., Maddern, H. N. C., Elliott, D. H. (1995) A Simple Emergency Underwater Breathing Aid for Helicopter Escape. Aviat. Space Environ. Med. 1995; 66:206-11.

69. Tipton, M. J., Franks, C. M., Sage, B. A., Redman, P. J. (1997) An Examination of Two Helicopter Emergency Breathing Aids for Use During Helicopter Underwater Escape. Aviat. Space Environ. Med. 1997; 68:907-14.

70. Turner, G.M., Johnson, P.A. Review of Helicopter Ditching Accidents. DERA Report PLSD/CHS5/CR97009/1.0. February 1997.

71. United States Naval Safety Centre. Helicopter Howgowzit. 1983 - 1985.

72. United States Naval Experimental Diving Unit. Report NAVSEA TA 90-003. May 1995.

73. Yacavone, D.W. Underwater Helicopter Egress Scenarios Regarding Naval Safety Centre Aeromedical Newsletter. No 91-3. September 1991.

74. Vyrnwy-Jones, P. & Turner, J. M. (1988) A Review of RN Helicopter Accidents 1972-84. RAF, IAM Report No. 648.

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14. Abstract

This AGARDograph provides the latest worldwide statistics on survivability from a helicopter ditching. It concludes that the persistent 15% fatality rate is basically caused by drowning. The principal cause of drowning is due to inability to breath-hold long enough to make an escape.

The provision of some form of Emergency Breathing System (EBS), whether a re-breather or compressed air unit, would extend the time underwater and hence improve survivability. The development of such units since the Second World War are described, and current available units are included to aid NATO and PfP Nations to review their choice. The importance of producing a course training package prior to the introduction of any new EBS into service is presented. Two examples are specifically cited. Finally, a summary is made of the current EBS situation as we enter into the 21st Century.

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